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Paley

PALEY'S

NATURAL THEOLOGY;

WITH

ILLUSTRATIVE NOTES,

BY

HENRY, LORD BROUGHAM, F.R.S., AND SIR C. BELL, K.G.H., &c.

AND AN INTRODUCTORY

DISCOURSE OF NATURAL THEOLOGY,

BY LORD BROUGHAM:

TO WHICH ARE ADDED,

SUPPLEMENTARY DISSERTATIONS,
AND A TREATISE ON ANIMAL MECHANICS,
BY SIR CHARLES BELL.

WITH NUMEROUS WOODCUTS.

IN FOUR VOLS. VOL. III.

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NATURAL THEOLOGY.

CHAPTER XVII.

THE RELATION OF ANIMATED BODIES TO INANIMATE NATURE.

We have already considered *relation*, and under different views; but it was the relation of parts to parts, of the parts of an animal to other parts of the same animal, or of another individual of the same species.

But the bodies of animals hold, in their constitution and properties, a close and important relation to natures altogether external to their own: to inanimate substances, and to the specific qualities of these; *e. g.*, *they hold a strict relation to the* ELEMENTS *by which they are surrounded.*

I. Can it be doubted, whether the *wings of birds* bear a relation to air, and the *fins of fish* to water? They are instruments of motion severally suited to the properties of the medium in which the motion is to be performed; which properties are different. Was not this difference contemplated when the instruments were differently constituted?

II. The structure of the animal *ear* depends for its use not simply upon being surrounded by a fluid, but upon the specific nature of that fluid. Every fluid would not serve: its particles must repel one another: it must form an elastic medium: for it is by the successive pulses of *such* a medium that the undulations excited by the surrounding body are carried to the organ; that a communication is formed between the object and the sense; which must be done, before the internal machinery of the *ear, subtile as it is,* can act at all.

III. The *organs* of voice and respiration are, n les than the ear, indebted, for the success of their operation, to the peculiar qualities of the fluid in which the animal is immersed. They, therefore, as well as the ear, are constituted upon the supposition of such a fluid, *i. e.*, of a fluid with such particular properties, being always present. Change the properties of the fluid, and the organ cannot act; change the organ, and the properties of the fluid would be lost. The structure, therefore, of our organs, and the properties of our atmosphere, are made for one another. Nor does it alter the relation, whether you allege the organ to be made for th element (which seems the most natural way of considering it), or the element as prepared for the organ.

IV. But there is another fluid with which we have t do; with properties of its own; with laws of acting, an of being acted upon, totally different from those of ai and water: and that is *light*. To this new, this singu lar element—to qualities perfectly peculiar, perfectl distinct and remote from the qualities of any other sub stance with which we are acquainted—an organ i adapted, an instrument is correctly adjusted, not le peculiar amongst the parts of the body, not less singul in its form and in the substance of which it is compose not less remote from the materials, the model, and th analogy of any other part of the animal frame, than th element to which it relates is specific amidst the su stances with which we converse. If this does not prov appropriation, I desire to know what would prove it.

Yet the element of light and the organ of visio however related in their office and use, have no co nexion whatever in their original. The action of ra of light upon the surfaces of animals has no tendency breed eyes in their heads. The sun might shine for ev upon living bodies, without the smallest approach t wards producing the sense of sight. On the other han also, the animal eye does *not* generate or emit light.

V. Throughout the universe there is a wonderf *proportioning* of one thing to another. The size of an *mals, the* human animal especially, when conside ᵗ respect to other animals, or to the plants which ᵛ around him, is such as a regard to his conveniency ıld have pointed out. A giant or a pigmy could not e milked goats, reaped corn, or mowed grass; we ʳ add, could not have rode a horse, trained a vine, rn a sheep, with the same bodily ease as we do, if ll. A pigmy would have been lost amongst rushes, arried off by birds of prey.[1]

t may be mentioned, likewise, that the model and materials of the human body being what they are, a h greater bulk would have broken down by its own ght. The persons of men who much exceed the nary stature betray this tendency.

I. Again (and which includes a vast variety of par- lars, and those of the greatest importance), how e is the *suitableness* of the earth and sea to their ral inhabitants; and of these inhabitants to the es of their appointed residence!

ake the *earth* as it is; and consider the correspon- y of the powers of its inhabitants with the proper- and condition of the soil which they tread. Take inhabitants as they are; and consider the substances ch the earth yields for their use. They can scratch urface, and its surface supplies all which they want. s is the length of their faculties; and such is the stitution of the globe, and their own, that this is cient for all their occasions.

Vhen we pass from the earth to the *sea*, from land vater, we pass through a great change: but an ade- te change accompanies us of animal forms and func- s, of animal capacities and wants; so that *correspon- y* remains. The earth in its nature is very different ı the sea, and the sea from the earth, but one accords ı its inhabitants as exactly as the other.

II. The last relation of this kind which I shall ıtion is that of *sleep* to *night;* and it appears to me e a relation which was expressly intended. Two ts are manifest: first, that the animal frame requires p; secondly, that night brings with it a silence and

---

[1] *See the Appendix,* on the bones of huge animals.

a cessation of activity which allows of sleep being take
without interruption and without loss. Animal existen
is made up of action and slumber; nature has provide
a season for each. An animal which stood not in nee
of rest would always live in daylight. An animal whic
though made for action, and delighting in action, mu
have its strength repaired by sleep, meets, by its co
stitution, the returns of day and night. In the hum
species, for instance, were the bustle, the labour, th
motion of life upheld by the constant presence of ligh
sleep could not be enjoyed without being disturbed b
noise, and without expense of that time which th
eagerness of private interest would not contentedly re
sign. It is happy, therefore, for this part of the cre
tion, I mean that it is conformable to the frame an
wants of their constitution, that nature, by the ve
disposition of her elements, has commanded, as it wer
and imposed upon them, at moderate intervals, a gener
intermission of their toils, their occupations, and pursuit

But it is not for man, either solely or principally, th
night is made. Inferior but less perverted natures tas
its solace, and expect its return with greater exactne
and advantage than he does. I have often observe
and never observed but to admire, the satisfaction, n
less than the regularity, with which the greatest part
the irrational world yield to this soft necessity, th
grateful vicissitude; how comfortably the birds of th
air, for example, address themselves to the repose
the evening, with what alertness they resume the act
vity of the day.

Nor does it disturb our argument to confess that ce
tain species of animals are in motion during the nig
and at rest in the day. With respect even to them,
is still true that there is a change of condition in th
animal, and an external change corresponding with i
There is still the relation, though inverted. The fa
is that the repose of other animals sets these at libert
and invites them to their food or their sport.

If the relation of *sleep* to *night*, and, in some instance
its converse, be real, we cannot reflect without ama

ıpon the extent to which it carries us. Day and
are things close to us; the change applies imme-
r to our sensations; of all the phenomena of nature,
ıe most obvious and the most familiar to our ex-
ce; but, in its cause, it belongs to the great mo-
which are passing in the heavens. Whilst the
glides round her axle she ministers to the alternate
ities of the animals dwelling upon her surface, at the
ime that she obeys the influence of those attrac-
vhich regulate the order of many thousand worlds.
elation, therefore, of sleep to night is the relation
inhabitants of the earth to the rotation of their
probably it is more, it is a relation to the system
ch that globe is a part; and, still further, to the
gation of systems of which theirs is only one. If
ccount be true, it connects the meanest individual
he universe itself,—a chicken roosting upon its
with the spheres revolving in the firmament.[2]

thing is more true than that the strength of the bones
e power of the muscles stand in intimate relation with
ight of the body, that is also, in relation with the at-
n of the globe itself. It is no less certain that many
living properties of animals, the condition of the
s system, and the alternation of exertion and repose
muscular system, are related to the change of day and
or to the revolving of our planet upon its axis. In
e may see a slight deviation in his habits and occu-
from this correspondence with the succession of
nd darkness; yet he enjoys a return of energy and
ty of spirits, which is followed by weariness and ex-
n; and health will not long continue without yielding
alternate condition of activity and repose. In nothing
see the benevolence of the Creator more than in the
ed gratification consequent on this arrangement alone,
ore especially in the brutes. It is not a mere effect of
nd the freshness of the morning which produces the
universal animation and activity of that time of day;
many animals the light of day is the signal to seek
; and that it is not the mere necessity which brings
s abroad at night, in order to feed secluded, or escape
nemies, *we know* from this, that their organs are
to the obscurer light and not their organs only, but

VIII. But if any one object to our represen
that the succession of day and night, or the rota

their propensities; for they are as full of activity and
ment as the things of day. The history of pulmona
other complaints indicates a curious connexion betwe
functions of the body and the revolution of time o
nations of day and night.

But the most remarkable accommodation of the ec
of animals, and of the property of life itself in them, i
the changes of the year rather than the diurnal c
How much this prevails in the vegetable world we ha
to look around us fully to comprehend. With the dim
of heat vegetation is nipped, the ova of insects locl
and the food of many animals withdrawn. Some a
could not be protected by an instinct of migration,
without the means of passage: the bat could not fl
with the swallow, nor the hedgehog and dormouse
with the deer. To sustain the animal heat against t
temperature of the surrounding atmosphere requires
rous circulation of the blood and a plentiful and u
rupted supply of food. Many animals must therefor
died during the winter had not nature supplied a m
their continuance in life beyond the ingenuity of i
conceive. The warmth of their clothing, and the i
to build themselves a warm habitation, which we
almost say were the exercise of ingenuity, are insu
To sustain life they must hold it by a new tenure. A
ingly the necessity for food is removed; the activity
circulation is diminished remarkably; a torpor seiz
every living faculty, and they fall into what seems
sleep. Yet it is not sleep, but a new condition of ex
in which life is preserved without the necessity for fo
when all the functions of the system are let down to a
state of activity. And justly, therefore, it has been sa
in these things we trace the benevolence of the C
"who did not cast his living creatures into the w
prosper or perish as they might find it suited to them
but fitted together with the nicest skill the world a
constitution which he gave to its inhabitants; so fasl
it, that light and darkness, sun and air, moist and dry,
become their ministers and benefactors, the unweari
unfailing causes of their well-being."—*Whewell's*
water Treatise.

th upon which it depends, is not resolvable into attraction, we will refer him to that which cer- s,—to the change of the seasons. Now the con- n of animals susceptible of torpor bears a relation ter similar to that which sleep bears to night. t not only the cold, but the want of food, which proach of winter induces, the Preserver of the has provided in many animals by migration, in thers by torpor. As one example out of a thou- he bat, if it did not sleep through the winter, ve starved; as the moths and flying insects upon it feeds disappear. But the transition from sum- winter carries us into the very midst of physical my, that is to say, into the midst of those laws govern the solar system at least, and probably heavenly bodies.

CHAPTER XVIII.

INSTINCTS.

THE order may not be very obvious by which I pla *instincts* next to relations. But I consider them as species of relation. They contribute, along with th animal organization, to a joint effect, in which view the are related to that organization. In many cases the refer from one animal to another animal; and, when th is the case, become strictly relations in a second poi of view.

An INSTINCT is a propensity prior to experience an independent of instruction. We contend that it is b *instinct* that the sexes of animals seek each other; th animals cherish their offspring; that the young qua ruped is directed to the teat of its dam; that birds buil their nests and brood with so much patience upon the eggs; that insects which do not sit upon their eggs d posit them in those particular situations in which th young when hatched find their appropriate food; that is instinct which carries the salmon, and some other fish out of the sea into rivers, for the purpose of sheddin their spawn in fresh water.

We may select out of *this* catalogue the incubation eggs. I entertain no doubt but that a couple of spa rows hatched in an oven, and kept separate from th rest of their species, would proceed as other sparrov do in every office which related to the production an preservation of their brood. Assuming this fact,[3] th thing is inexplicable upon any other hypothesis than that of an instinct impressed upon the constitution of the animal. For, first, what should induce the female bird to prepare a nest before she lays her eggs? It is in vain to suppose her to be possessed of the faculty of reasoning; for no reasoning will reach the case. The fulness or distension which she might feel in a particular part of the body, from the growth and solidity of the egg within her, could not possibly inform her that she was about to produce something which, when produced, was to be preserved and taken care of. Prior to experience there was nothing to lead to this inference, or to this suspicion. The analogy was *all* against it; for, in every other instance, what issued from the body was cast out and rejected.

---

[3] There can be very little doubt of this assumption bein according to the fact. Nevertheless, as the experiment h probably not been actually made, there is no harm in me tioning one or two examples of the same import, and whi

But, secondly, let us suppose the egg to be produced into day; how should birds know that their eggs contain their young? There is nothing either in the aspect or in the internal composition of an egg which could lead even the most daring imagination to conjecture that

are ascertained by repeated observation. When caterpillars bred upon a tree are shaken off and fall for the first time upon the ground, they immediately regain the tree by crawling up as quick as they can. Again—it is a very general law of insects, that the grub feeds upon a food which the parent does not eat, and yet the latter makes provision for the grub. Thus the solitary wasp deposits its eggs, each in a hole, and then collects a certain number of green worms, which she rolls up and deposits in the same hole, over the egg. When the grub is hatched, it feeds upon these worms until transformed into a young wasp. And here two things are remarkable: first, the wasp itself never feeds upon the worm, or indeed on any animal food; and next, M. Réaumur found that she provides just enough of the worms to sustain the grub till it becomes a fly, and changes its food. Our author dwells afterwards upon the application to the argument of the fact that the parent insect never sees its young. The architecture of bees affords perhaps the most striking illustration; for those which have been taken without ever having any *communication* with the former race, build *precisely in the accustomed* manner. See the next note.

it was hereafter to turn out from under its shell a living perfect bird. The form of the egg bears not the rudiments of a resemblance to that of the bird. Inspecting its contents, we find still less reason, if possible, to look for the result which actually takes place. If we should go so far as, from the appearance of order and distinction in the disposition of the liquid substances which we noticed in the egg, to guess that it might be designed for the abode and nutriment of an animal (which would be a very bold hypothesis), we should expect a tadpole dabbling in the slime, much more than a dry, winged, feathered creature, a compound of parts and properties impossible to be used in a state of confinement in the egg, and bearing no conceivable relation, either in quality or material, to anything observed in it. From the white of an egg, would any one look for the feather of a goldfinch? or expect from a simple uniform mucilage the most complicated of all machines, the most diversified of all collections of substances? Nor would the process of incubation, for some time at least, lead us to suspect the event. Who that saw red streaks shooting in the fine membrane which divides the white from the yolk would suppose that these were about to become bones and limbs? Who that espied two discoloured points first making their appearance in the cicatrix, would have had the courage to predict that these points were to grow into the heart and head of a bird? It is difficult to strip the mind of its experience. It is difficult to resuscitate surprise when familiarity has once laid the sentiment asleep. But could we forget all that we know, and which our sparrows never knew, about oviparous generation—could we divest ourselves of every information but what we derived from reasoning upon the appearances or quality discovered in the objects presented to us—I am convinced that Harlequin coming out of an egg upon the stage is not more astonishing to a child than the hatching of a chicken both would be, and ought to be, to a philosopher.[4]

[4] *The manner* in which the chicken breaks the egg is one *of the most* wonderful operations of instinct, and is a process

But admit the sparrow by some means to know that within that egg was concealed the principle of a future bird: from what chemist was she to learn that *warmth* was necessary to bring it to maturity, or that the degree of warmth imparted by the temperature of her own body was the degree required?

To suppose, therefore, that the female bird acts in this process from a sagacity and reason of her own, is to suppose her to arrive at conclusions which there are no premises to justify. If our sparrow, sitting upon her eggs, expect young sparrows to come out of them, she forms, I will venture to say, a wild and extravagant expectation, in opposition to present appearances and to probability. She must have penetrated into the order of nature farther than any faculties of ours will carry us; and it hath been well observed, that this deep sagacity, if it be sagacity, subsists in conjunction with great stupidity, even in relation to the same subject. "A chemical operation," says Addison, "could not be followed with greater art or diligence than is seen in hatching a chicken; yet is the process carried on without the least glimmering of thought or common sense. The hen will mistake a piece of chalk for an egg—is insensible of the ncrease or diminution of their number—does not distinguish between her own and those of another species

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marked by the uniformity of instincts. For as all bees build alike with respect to the size of the cell and the angles at which its planes are inclined, so M. Réaumur found that all chickens chip the shell in the same direction, from left to right; and that the circle in which they chip invariably cuts the egg at right angles to its transverse axis, and not obliquely. The instrument which the chicken employs is a mall protuberance on its upper mandible, called the *bill-scale,* which has no other use, and accordingly drops off soon after the bird is hatched. If any one should consider this as a different operation in kind from those usually ascribed to nstinct in animals that are formed, a little reflection will probably show him the impossibility of drawing any such line of distinction. See the Dissertation on Instinct, Appendix.

—is frightened when her supposititious breed of ducklings take the water."

But it will be said, that what reason could not do for the bird, observation, or instruction, or tradition might. Now if it be true that a couple of sparrows, brought up from the first in a state of separation from all other birds, would build their nest, and brood upon their eggs, then there is an end of this solution. What can be the traditionary knowledge of a chicken hatched in an oven?

Of young birds taken in their nests, a few species breed when kept in cages; and they which do so build their nests nearly in the same manner as in the wild state, and sit upon their eggs. This is sufficient to prove an instinct without having recourse to experiments upon birds hatched by artificial heat, and deprived from their birth of all communication with their species; for we can hardly bring ourselves to believe that the parent bird informed her unfledged pupil of the history of her gestation, her timely preparation of a nest, her exclusion of the eggs, her long incubation, and of the joyful eruption at last of her expected offspring: all which the bird in the cage must have learnt in her infancy if we resolve her conduct into *institution.*

Unless we will rather suppose that she remembers her own escape from the egg—had attentively observed the conformation of the nest in which she was nurtured—and had treasured up her remarks for future imitation; which is not only extremely improbable, (for who that sees a brood of callow birds in their nest can believe that they are taking a plan of their habitation?) but leaves unaccounted for one principal part of the difficulty, "the preparation of the nest before the laying of the egg." This she could not gain from observation in her infancy.

It is remarkable also, that the hen sits upon eggs which she has laid without any communication with the male, and which are therefore necessarily unfruitful. That secret she is not let into. Yet if incubation had been a subject of instruction or of tradition, it should *seem* that this distinction would have formed part of the *lesson:* whereas the instinct of nature is calculated for a

of nature—the exception here alluded to taking
chiefly, if not solely, amongst domesticated fowls,
ich nature is forced out of her course.

ere is another case of oviparous economy, which is
less likely to be the effect of education than it is
in birds, namely, that of *moths* and *butterflies*,
deposit their eggs in the precise substance—that
abbage for example—from which, not the butterfly
lf, but the caterpillar which is to issue from her
draws its appropriate food. The butterfly cannot
the cabbage: cabbage is no food for her; yet in
bbage, not by chance, but studiously and electively,
ays her eggs. There are, amongst many other
, the willow-caterpillar and the cabbage-caterpillar;
e never find upon a willow the caterpillar which
he cabbage, nor the converse. This choice, as ap-
to me, cannot in the butterfly proceed from in-
ion. She had no teacher in her caterpillar state.
never knew her parent. I do not see, therefore,
knowledge acquired by experience, if it ever were
could be transmitted from one generation to an-
. There is no opportunity either for instruction
itation. The parent race is gone before the new
is hatched. And if it be original reasoning in the
fly, it is profound reasoning indeed. She must
nber her caterpillar state, its tastes and habits, of
memory she shows no signs whatever. She must
ide from analogy (for here her recollection cannot
her), that the little round body which drops from
bdomen will at a future period produce a living
re, not like herself, but like the caterpillar which
members herself once to have been. Under the
nce of these reflections, she goes about to make
ion for an order of things which she concludes will
time or other take place. And it is to be observed,
ot a few out of many, but that all butterflies argue
all draw this conclusion; all act upon it.

suppose the address, and the selection, and the
which we *perceive* in the preparations which
irrational animals make for their young, to be

e probable origin, still there is left to
that which is the source and foundation
ena, that which sets the whole at work, t
arental affection, which I contend to be i
pon any other hypothesis than that of i

hall hardly, I imagine, in brutes, refer th
wards their offspring to a sense of duty or
care of reputation, a compliance with publ
with public laws, or with rules of life built up
perience of their utility. And all attempts
for the parental affection from association,
il. With what is it associated? Most imm
with the throes of parturition, that is, with pai
or, and disease. The more remote, but not le
association, that which depends upon analogy,
nst it. Everything else which proceeds from tl
s cast away and rejected. In birds is it the eg
the hen loves? or is it the expectation which sl
hes of a future progeny that keeps her upon h
? What cause has she to expect delight from h
eny? Can any rational answer be given to t
tion, why, prior to experience, the brooding h
ld look for pleasure from her chickens? It d
I think, appear that the cuckoo ever knows
ng; yet, in her way, she is as careful in making
n for them as any other bird. She does not l
egg in every hole.

he salmon suffers no surmountable obstacle to o
progress up the stream of fresh rivers. And
she do there? She sheds a spawn, which sh
iately quits in order to return to the sea; ar
e of her body she never afterwards recognizes
e whatever. Where shall we find a motive
ts and her perseverance? Shall we seek
entation or in instinct? The violet crab of
rms a fatiguing march of some months' cor
[illegible] to the sea-side. When sh
[illegible] her spawn into the open
[illegible] turn home.

Moths and butterflies, as hath already been observed, k out for their eggs those precise situations and subnces in which the offspring caterpillar will find its ropriate food. That dear caterpillar the parent butly must never see. There are no experiments to ve that she would retain any knowledge of it if she . How shall we account for her conduct? I do not n for her art and judgment in selecting and securing aintenance for her young, but for the impulse upon ch she acts. What should induce her to exert any or judgment, or choice, about the matter? The unlosed grub, the animal which she is destined not to w, can hardly be the object of a particular affection, e deny the influence of instinct. There is nothing, efore, left to her, but that of which her nature seems pable, an abstract anxiety for the general preserva- of the species—a kind of patriotism—a solicitude the butterfly race should cease from the creation.

astly, the principle of association will not explain the ontinuance of the affection when the young animal grown up. Association operating in its usual way ld rather produce a contrary effect. The object ld become more necessary by habits of society; reas birds and beasts, after a certain time, banish r offspring, disown their acquaintance, seem to have n no knowledge of the objects which so lately ensed the attention of their minds and occupied the stry and labour of their bodies. This change, in rent animals, takes place at different distances of from the birth; but the time always corresponds n the ability of the young animal to maintain itself, er anticipates it. In the sparrow tribe, when it is eived that the young brood can fly and shift for nselves, then the parents forsake them for ever; and, gh they continue to live together, pay them no more ntion than they do to other birds in the same flock.* lieve the same thing is true of all gregarious quapeds.[5]

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* Goldsmith's *Natural History*, vol. iv. p. 244.

In the natural and instinctive feelings of man, as con-

In this part of the case the variety of resources, expedients, and materials which animals of the same species are said to have recourse to under different circumstances, and when differently supplied, makes nothing against the doctrine of instincts. The thing which we want to account for is the propensity. The propensity being there, it is probable enough that it may put the animal upon different actions according to different exigencies. And this adaptation of resources may look like the effect of art and consideration rather than of instinct; but still the propensity is instinctive. For instance, suppose what is related of the woodpecker to be true, that in Europe she deposits her eggs in cavities which she scoops out in the trunks of soft or decayed trees, and in which cavities the eggs lie concealed from the eye, and in some sort safe from the hand of man, but that, in the forests of Guinea and the Brazils, which man seldom frequents, the same bird hangs her nest on the twigs of tall trees, thereby placing them out of the reach of *monkeys* and *snakes*—*i. e.*, that in each situation she prepares against the danger which she has most occasion to apprehend. Suppose, I say, this to be true, and to be alleged, on the part of the bird that builds these nests, as evidence of a reasoning and distinguishing precaution: still the question returns, whence the propensity to build at all?

Nor does parental affection accompany generation by any universal law of animal organization, if such a thing were intelligible. Some animals cherish their progeny with the most ardent fondness, and the most assiduous

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tradistinguished from those which have been modified by reason, something of the same kind may be observed. The mutual relation of protection and dependence, produced by power and weakness, is of this description. A helpless infant excites much stronger sympathy in the mother than the child that can shift for itself; and hence the partiality, accompanied by blindness to defects, which most parents entertain towards children whose natural deficiency, whether bodily or mental, throws them on their care long after the *season of infancy.*

attention; others entirely neglect them; and this distinction always meets the constitution of the young animal with respect to its wants and capacities. In many, the parental care extends to the young animal; in others, as in all oviparous fish, it is confined to the egg, and even as to that, to the disposal of it in its proper element. Also, as there is generation without parental affection, so is there parental instinct, or what exactly resembles it, without generation. In the bee tribe, the grub is nurtured neither by the father nor the mother, but by the neutral bee. Probably the case is the same with ants.

I am not ignorant of the theory which resolves intinct into sensation, which asserts that what appears to have a view and relation to the future, is the result only f the present disposition of the animal's body, and of pleasure or pain experienced *at the time*. Thus the inubation of eggs is accounted for by the pleasure which he bird is supposed to receive from the pressure of the mooth convex surface of the shells against the abdomen, r by the relief which the mild temperature of the egg may afford to the heat of the lower part of the body, which is observed at this time to be increased beyond its sual state. This present gratification is the only move with the hen for sitting upon her nest; the hatching f the chickens is, with respect to her, an accidental consequence. The affection of viviparous animals for heir young is in like manner solved by the relief, and erhaps the pleasure, which they perceive from giving ıck. The young animal's seeking, in so many inances, the teat of its dam, is explained from its sense smell, which is attracted by the odour of milk. The almon's urging its way up the stream of fresh-water vers is attributed to some gratification or refreshment hich, in this particular state of the fish's body, she receives from the change of element. Now of this theory may be said,—

First, that of the cases which require solution, there e few to which it can be applied with tolerable probality; *that there are none* to which it can be applied without strong objections, furnished by the circumstances of the case. The attention of the cow to its calf, and of the ewe to its lamb, appear to be prior to their sucking. The attraction of the calf or lamb to the teat of the dam, is not explained by simply referring it to the sense of smell. What made the scent of milk so agreeable to the lamb that it should follow it up with its nose, or seek with its mouth the place from which it proceeded? No observation, no experience, no argument could teach the new-dropped animal that the substance from which the scent issued was the material of its food. It had never tasted milk before its birth. None of the animals which are not designed for that nourishment ever offer to suck, or to seek out any such food. What is the conclusion, but that the sugescent parts of animals are fitted for their use, and the knowledge of that use put into them?

We assert, secondly, that, even as to the cases in which the hypothesis has the fairest claim to consideration, it does not at all lessen the force of the argument for intention and design. The doctrine of instinct is that of appetencies, *superadded* to the constitution of an animal, for the effectuating of a purpose beneficial to the species. The above-stated solution would derive these appetencies from organization; but then this organization is not less specifically, not less precisely, and, therefore, not less evidently adapted to the same ends, than the appetencies themselves would be upon the old hypothesis. In this way of considering the subject, sensation supplies the place of foresight: but this is the effect of contrivance on the part of the Creator. Let it be allowed, for example, that the hen is induced to brood upon her eggs by the enjoyment or relief which, in the heated state of her abdomen, she experiences from the pressure of round smooth surfaces, or from the application of a temperate warmth. How comes this extraordinary heat or itching, or call it what you will, which you suppose to be the cause of the bird's inclination, to be felt just at the time when the inclination itself *is wanted*: when it tallies so exactly with the internal constitution of the egg, and with the help which that constitution requires in order to bring it to maturity? In my opinion, this solution, if it be accepted as to the fact, ought to increase, rather than otherwise, our admiration of the contrivance.[6] A gardener lighting up his stoves, just when he wants to force his fruit, and when his trees require the heat, gives not a more certain evidence of design. So again; when a male and female sparrow come together, they do not meet to confer upon the expediency of perpetuating their species. As an abstract proposition, they care not the value of a barleycorn whether the species be perpetuated, or not: they follow their sensations, and all those consequences ensue which the wisest counsels could have dictated, which the most solicitous care of futurity, which the most anxious concern for the sparrow-world, could have produced. But how do these consequences ensue? The sensations, and the constitution upon which they depend, are as manifestly directed to the purpose which we see fulfilled by them; and the train of intermediate effects as manifestly laid and planned with a view to that purpose: that is to say, design is as completely evinced by the phenomena, as it would be, even if we suppose the operations to begin or to be carried on, from what some will allow to be alone properly called instincts, that is, from desires directed to a future end, and having no accomplishment or gratification distinct from the attainment of that end.

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[6] Whether we regard the argument of existence, or of attributes, the truth here glanced at is of extreme importance, and it pervades the whole of Natural Theology. It will be more fully illustrated in the Appendix, and in the notes to the subsequent chapters. When sceptics think they have destroyed one reason for believing in the skill or in the goodness of the Deity, by an explanation of the means used for producing some given effect, they only remove our admiration and our gratitude from one point to another, and often augment both the one and the other. Suppose it were discovered, contrary to all probability, that the bee makes the angles of 109° 28′ and 70° 32′ by means of some bodily conformation which secures this result,—some form of its own parts answering to those angles, if such a thing can be conceived; the wonder is only removed from the working of the insect without a tool to its using a tool provided for it by the intelligence which had solved the problem of maxima and minima, whence this conformation is a corollary. Again,—the loss of one sense, as the sight, quickens our perceptions through the organs of those senses which remain,—as touch and hearing. It is most probable that this effect is produced by the influence of habit, and has no direct connexion with the loss sustained. But habit might have had no such effect, and it might have blunted instead of sharpening; its effect tends to lessen the evil of the loss sustained; and it produces this advantage just as much as if the compensation had been the direct and immediate consequence of that loss. We are not here arguing the question of evil: that will be treated of hereafter, and it is common to both suppositions; both to the case of immediate and of mediate compensation. Again,—suppose, in generalizing, we could resolve all intellectual phenomena into some one principle, as association,—all moral into some other, as habit,—all physical into some third, as gravitation;—nay, suppose the doctrines of some materialists to prevail, and that all mental and all physical phenomena were resolvable into the operations of some sub-

In a word: I should say to the patrons of this opinion, Be it so; be it that those actions of animals which we refer to instinct are not gone about with any view to their consequences, but that they are attended in the animal with a present gratification, and are pursued for the sake of that gratification alone; what does all this prove, but that the *prospection*, which must be somewhere, is not in the animal, but in the Creator?

In treating of the parental affection in brutes, our business lies rather with the origin of the principle, than

tile fluid,—this would surely not weaken the arguments for the unity of the Deity, if indeed it did not rather strengthen them; it would in no degree detract from our conviction of his skill, nor even of the variety of its operations; and it would leave the argument as to goodness exactly where it stood before.—See Appendix, Dissertation upon Evil.

with the effects and expressions of it. Writers recount these with pleasure and admiration. The conduct of many kinds of animals towards their young has escaped no observer, no historian of nature. "How will they caress them," says Derham, "with their affectionate notes; lull and quiet them with their tender parental voice; put food into their mouths; cherish and keep them warm; teach them to pick, and eat, and gather food for themselves; and, in a word, perform the part of so many nurses, deputed by the Sovereign Lord and Preserver of the world to help such young and shiftless creatures!" Neither ought it, under this head, to be forgotten how much the instinct *costs* the animal which feels it; how much a bird, for example, gives up by sitting upon her nest; how repugnant it is to her organization, her habits, and her pleasures. An animal, formed for liberty, submits to confinement in the very season when everything invites her abroad: what is more, an animal delighting in motion, made for motion, all whose motions are so easy, and so free, hardly a moment, at other times, at rest, is, for many hours of many days together, fixed to her nest, as close as if her limbs were tied down by pins and wires. For my part, I never see a bird in that situation but I recognize an invisible hand, detaining the contented prisoner from her fields and groves, for the purpose, as the event proves, the most worthy of the sacrifice, the most important, the most beneficial.

But the loss of liberty is not the whole of what the procreant bird suffers. Harvey tells us that he has often found the female wasted to skin and bone by sitting upon her eggs.

One observation more, and I will dismiss the subject. The *pairing* of birds, and the *non-pairing* of beasts, forms a distinction between the two classes, which shows that the conjugal instinct is modified with a reference to utility founded on the condition of the offspring. In quadrupeds, the young animal draws its nutriment from the body of the *dam*. The male parent neither does nor can contribute any part to its sustentation. In the winged race, the young bird is supplied by an importation of food, to procure and bring home which, in a sufficient quantity for the demand of a numerous brood, requires the industry of both parents. In this difference, we see a reason for the vagrant instinct of the quadruped, and for the faithful love of the feathered mate.

CHAPTER XIX.

OF INSECTS.

We are not writing a system of natural history; therefore we have not attended to the classes into which th subjects of that science are distributed. What we ha to observe concerning different species of animals, fel easily, for the most part, within the divisions which th course of our argument led us to adopt. There remain however, some remarks, upon the *insect* tribe, whicl could not properly be introduced under any of thes heads; and which therefore we have collected into chapter by themselves.

The structure, and the use of the parts, of insects, ar less understood than that of quadrupeds and birds, no only by reason of their minuteness, or the minuteness o their parts (for that minuteness we can, in some measure follow with glasses), but also by reason of the remotenes of their manners and modes of life from those of large animals. For instance: Insects, under all their varietie of form, are endowed with *antennæ*,[7] which is the nam given to those long feelers that rise from each side of the head: but to what common use or want of the insect kind a provision so universal is subservient has not yet been ascertained; and it has not been ascertained, because it admits not of a clear, or very probable, comparison with any organs which we possess ourselves, or with the organs of animals which resemble ourselves in their functions and faculties, or with which we are better acquainted than we are with insects. We want a ground of analogy. This difficulty stands in our way as to some particulars in the insect constitution, which we might wish to be acquainted with. Nevertheless, there are many contrivances in the bodies of insects, neither dubious in their use nor obscure in their structure, and most properly mechanical. These form parts of our argument.

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[7] The most scientific entomologists consider the antenn of insects to be organs of hearing; this is the opinion o those who have minutely examined their structure; wherea very many entomologists contend that the antennæ are organs of feeling, observing that many insects are constantl touching surrounding objects with them, such as the be tribe, ichneumonidæ, &c. The argument used against th latter opinion is, that although many insects do undoubtedl touch surrounding objects with their antennæ, yet man scrupulously avoid so doing, such as the butterfly and mot tribe, the Lamellicorn beetles, &c. When, however, - asked the *question, what* is hearing as distinguish *feeling, we find it* difficult to draw any line. Are

I. The *elytra*, or scaly wings of the genus of scarabæus or beetle, furnish an example of this kind. The true wing of the animal is a light, transparent membrane, finer than the finest gauze, and not unlike it. It is also, when expanded, in proportion to the size of the animal, very large. In order to protect this delicate structure, and, perhaps, also to preserve it in a due state of suppleness and humidity, a strong, hard case is given to it in the shape of the horny wing which we call the elytron. When the animal is at rest, the gauze wings lie folded up under this impenetrable shield. When the beetle prepares for flying, he raises the integument, and spreads out his thin membrane to the air. And it cannot be observed without admiration, what a tissue of cordage, *i. e.*, of muscular tendons, must run in various and complicated, but determinate directions, along this fine surface, in order to enable the animal, either to gather it up into a certain precise form, whenever it desires to place its wings under the shelter which nature

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mere modifications of the same thing? and as the antennæ of insects are so exceedingly variable in form, may they not be used as organs of touch in some, and of hearing in others?

hath given to them; or to expand again their folds when wanted for action.

In some insects the elytra cover the whole body;[8] in others, half; in others only a small part of it;[9] but in all,[10] they completely hide and cover the true wings. Also,

Many or most of the beetle species lodge in holes in the earth, environed by hard, rough substances, and have frequently to squeeze their way through narrow passages; in which situation, wings so tender, and so large, could scarcely have escaped injury, without both a firm covering to defend them, and the capacity of collecting themselves up under its protection.[11]

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[8] From this circumstance beetles (the tribe of insects to which the above description applies) have received the name of *Coleoptera*, from two Greek words signifying *sheath* and *wing*.

[9] A tribe of insects called the *Brachelytra* (or *Staphylinus* of Linnæus) possess wing-cases of this description.

[10] These are exceptions. In the genera *Molorchus*, *Sitaris* (and others might be enumerated among the beetle tribe), the wing-cases are small and narrow, and leave the wings exposed. The species of the genus *Molorchus*, however, do not require such protection for their wings, since they live in flowers. The habits of the *Sitaris* are not so well known; they are said to live in the nests of certain species of bees.

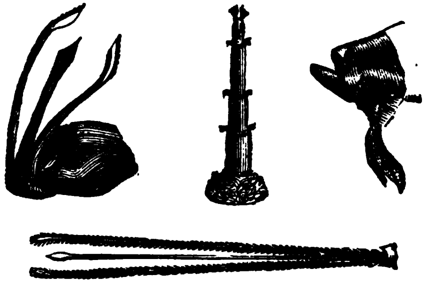
In the earwig the elytra do not entirely cover the wings; but the portion of the wing exposed is of a hornlike substance, like the elytra, whilst the remaining part of the wing is extremely delicate.

[11] A tribe of beetles, coming under the generic name of *Hister*, forms a good illustration of this mode of existence: in these insects the elytra are remarkably hard.

The species of the genus *Hister* possess remarkable analogical resemblances to tortoises, which have somewhat similar habits: like them, they are exceedingly hard, of an oval shape, and have the power of retracting the head beneath a horny covering; they are slothful, and very strong, and burrow in the ground by means of their fore legs.

A great analogical resemblance also exists b
insect *called the mole-cricket* and the mole, their
being similar.

II. Another contrivance, equally mechanical, equally clear, is the *awl*, or borer, fixed at the ta



various species of flies; and with which they pier some cases, plants; in others, wood; in others,[1] skin and flesh of animals; in others, the coat o chrysalis of insects of a different species from their

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[12] Almost every caterpillar (perhaps, without exce has its peculiar parasites among the ichneumonidæ, a ent tribe of insects: the same ichneumon almost inva choosing the same caterpillar to deposit its eggs upon and as the situations in which different caterpillars fe very various, so is the structure of their parasites. Th neumons which infest internal feeding caterpillars such as feed in the trunk of a tree, or the stem of a are furnished with long ovipositors to enable them to the caterpillar through some hole or chink where they selves cannot get.

Even the ichneumons are not free from parasites. are instances where four or five different parasitical i have been found in the same chrysalis (as that of the *T osoma leucorum*, a saw-fly), each one feeding upon the Thus several larvæ of an ichneumon may be found fe upon the inside of a chrysalis; and when these larvæ into pupæ or chrysalides, some of the chalcididæ, a *ent* tribe of flies, will feed upon them, and even some and in others, even lime, mortar, and stone.[13] I need not add, that having pierced the substance, they deposit their eggs in the hole. The descriptions which naturalists give of this organ are such as the following:—It is a sharp-pointed instrument, which, in its inactive state, lies concealed in the extremity of the abdomen, and which the animal draws out at pleasure, for the purpose of making a puncture in the leaves, stem, or bark, of the particular plant which is suited to the nourishment of its young. In a sheath, which divides and opens whenever the organ is used, there is inclosed a compact, solid, dentated stem, along which runs a *gutter* or *groove*, by which groove, after the penetration is effected, the egg, assisted in some cases by a peristaltic motion, passes to its destined lodgment. In the œstrum or gad-fly, the wimble[14] *draws out* like the pieces of a spy-glass: the last piece is armed with three hooks, and is able to bore through the hide of an ox. Can any thing more be necessary to display the mechanism, than to relate the fact?

III. The *stings*[15] of insects, though for a different purpose, are, in their structure, not unlike the piercer. The sharpness to which the point in all of them is wrought; the temper and firmness of the substance of which it is composed; the strength of the muscles by which it is darted out, compared with the smallness and weakness of the insect, and with the soft and friable texture of the rest of the body,—are properties of the sting to be noticed, and not a little to be admired. The sting of a *bee* will pierce through a goat-skin glove. It penetrates the human flesh more readily than the finest point of a needle. The *action* of the sting affords an example of the union of chemistry and mechanism, such as, if it be not a proof of contrivance, nothing is. First, as to the chemistry: how highly concentrated must be the *venom*, which, in so small a quantity, can produce such powerful effects! And in the bee we may observe that this venom is made from *honey*, the only food of the insect, but the last material from which I should have expected that an exalted poison could, by any process or digestion whatsoever, have been prepared. In the next place, with respect to the mechanism, the sting is not a simple but a compound instrument. The visible sting, though drawn to a point exquisitely sharp, is in strictness only a sheath, for, near to the extremity, may be perceived by the microscope two minute orifices, from which orifices, in the act of stinging, and, as it should seem, after the point of the main sting has buried itself in the flesh, are launched out two subtile rays, which may be called the true or proper stings, as being those through which the poison is infused into the puncture already made by the exterior sting. I have said that chemistry and mechanism are here *united:* by which observation I meant, that all this machinery would have been useless, *telum imbelle*, if a supply of poison, intense in quality, in proportion to the smallness of the drop, had not been furnished to it by the chemical elaboration which was carried on in the insect's body; and that, on the other hand, the poison, the result of this process, could not have attained its effect, or reached its enemy, if, when it was collected at the extremity of the abdomen, it had not found there a machinery fitted to conduct it to the external situations in which it was to operate, *viz.*, an awl to bore a hole, and a syringe to inject the fluid. Yet these attributes, though combined in their action, are independent in their origin. The venom does not breed the sting; nor does the sting concoct the venom.

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[13] There is not any accredited instance of any insects perforating so hard a substance as stone, with the 'awl or borer' fixed at the tail. This instrument, technically called ovipositor, is excessively variable in its structure, being scarcely alike in any two species: the description given will answer for that of the saw-fly (*Tenthredo*).

[14] Wimble, or *ovipositor.*

[15] *The stings of insects* are also used as ovipositors.

IV. The *proboscis*,[16] with which many insects are en-

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[16] The part called proboscis in the bee consists of a central stalk, or tongue, *a* (Fig. 1), and four lateral pieces, or jaws, *two of which spring from the base, and two have their origin near the middle.* The apical half of the stalk is soft and

Fig. 1.

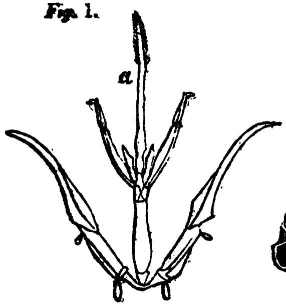
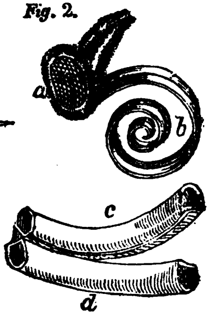


Fig. 2.



wed, comes next in order to be considered. It is a)e attached to the head of the animal; in the bee, it composed of two pieces, connected by a joint: for, if were constantly extended, it would be too much exsed to accidental injuries; therefore, in its indolent te, it is doubled up by means of the joint, and in that sition lies secure under a scaly pent-house.[17] In many ecies of the butterfly, the proboscis, when not in use, coiled up like a watch-spring. In the same bee, the)boscis serves the office of the mouth, the insect hav- no other;[18] and how much better adapted it is, than

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xible, rather flat, and covered with minute hairs: it is efly this part of the proboscis which is used in collecting ney. Honey is not sucked up as is generally supposed, : licked up, and then conveyed to the œsophagus. The r lateral pieces when closed form a sheath to protect the gue, and other parts of the central stalk. Fig. 2 represts the profile of a butterfly's head; *a* is the compound eye, l *b* the proboscis partially unfolded; *c* and *d* show porns of the tubes forming the proboscis highly magnified.

[7] There is an indentation in the under side of the head to eive the proboscis when folded up.

[8] A bee has the same number of parts to its mouth as any er insect; the only difference between that of a bee and a tle is, that *some of the* parts are more developed in the *ner: viz., the labium,* tongue, and maxillæ.

a mouth would be, for the collecting of the proper nourishment of the animal is sufficiently evident. The food of the bee is the nectar of flowers; a drop of syrup, lodged deep in the bottom of the corollæ, in the recesses of the petals, or down the neck of a monopetalous glove. Into these cells the bee thrusts its long narrow pump, through the cavity of which it sucks[19] up this precious fluid, inaccessible to every other approach. It is observable also, that the plant is not the worse[20] for what the bee does to it. The harmless plunderer rifles the sweets, but leaves the flower uninjured. The ringlets of which the proboscis of the bee is composed, the muscles by which it is extended and contracted, form so many microscopical wonders. The agility also with which it is moved can hardly fail to excite admiration. But it is enough for our purpose to observe, in general, the suitableness of the structure to the use of the means to the end, and especially the wisdom by which nature has departed from its most general analogy (for animals being furnished with mouths are such), when the purpose could be better answered by the deviation.

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[19] See Note 18. It might be more correct to say *licks up*, for there is no tube.

[20] Bees are essential to the fructification of many sorts of plants, for it is by them that the farina is carried from the male to the female flowers; and as some flowers yield a much greater quantity of honey than others, it might perhaps be imagined that those yielding little, and yet depending upon the bees for their fructification, might often be barren. No such defects, however, are to be found: the structure of the proboscis varies considerably in different species of bees, so that all bees cannot collect indiscriminately from any honey-yielding plant. One great tribe of bees (the *apidæ*) collect their honey for the most part from bell-shaped flowers, such as the blind nettle, &c.; their long proboscis enabling them to reach the bottom of the bells. Another tribe, having the proboscis short, are obliged to collect from flowers of a different shape. There is yet another circumstance which leads the different sorts of bees to visit a variety of flowers: *viz.*, that they do not feed their larvæ on the same substance. If we examine the cells of some (the *andrænidæ*), we find that the food stored up for the young consists of a ball of farina, which has scarcely any admixture of honey: these bees would naturally seek those flowers which yield the most farina; whereas in others (the *apidæ*) honey with very little farina is stored up for the *young*.

In some insects the proboscis, or tongue, or trunk, is shut up in a sharp-pointed sheath, which sheath,[21] being of a much firmer texture than the proboscis itself, as well as sharpened at the point, pierces the substance which contains the food, and then *opens within the wound*, to allow the enclosed tube, through which the juice is extracted, to perform its office. Can any mechanism be plainer than this is, or surpass this?

V. The *metamorphosis* of insects from grubs into moths and flies is an astonishing process. A hairy caterpillar is transformed into a butterfly. Observe the change. We have four beautiful wings where there were none before—a tubular proboscis in the place of a mouth with jaws and teeth,[22] six long legs instead of fourteen feet. In another case we see a white, smooth, soft worm turned into a black, hard, crustaceous beetle

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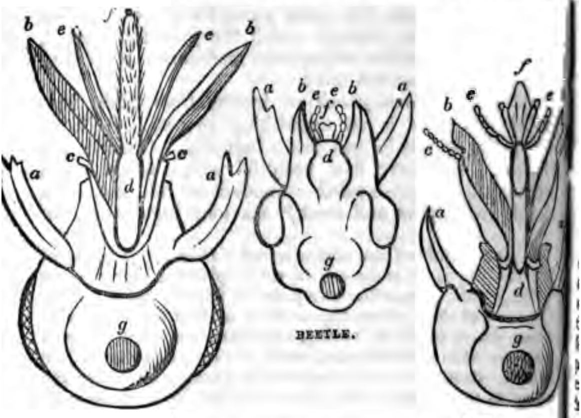
[21] The mouth of the common flea (*Pulex irritans*) is of this nature; it is composed of seven pieces, a pair of *mandibles*, a pair of *maxillæ*, two *palpi* or feelers, and a *tongue*. The uses of these pieces appear to be as follows:—the *mandibles*, which are short, strong, and sharp, are to cut through the outer skin; the *maxillæ*, which are long and shaped like lancets, are to pierce still deeper so as to cause bleeding: the *tongue* is then used to lick and convey the blood to the œsophagus; and the *palpi* are to direct these operations, conveying information to the animal by feeling or touch. These same seven parts (forming the mouth, and technically called *trophi*) are to be found in almost all insects, but constructed in different ways to suit the various habits of the species.

[22] The mouth of the caterpillar, or larva state of insects, has, in the greater portion of the species, the same number of parts as that of the perfect insect. In the pupa state some of these parts become nearly or quite obliterated, whilst others are much more developed to suit the habits of the animal in its next or perfect state of existence; and thus, of course, in some instances, where there *is* but little difference between the *habits of the larva* and those of the perfect insect, there is

likewise but little difference in the structure of the mouth, as, for instance, in locusts, grasshoppers, and cockroaches.

In the butterfly tribe the maxillæ or under jaws of the caterpillar become in the perfect insect elongated into two tubes (see Cut), which may be joined together at the pleasure of the animal, by means of projecting ridges (furnished with a sort of hook somewhat like the laminæ of feathers),



BEETLE.

HUMBLE BEE.

BEE.

a, a, mandibles; *c, c,* maxillary palpi; *e, e,* labial palpi;
b, b, maxillæ; *d, d,* labium; *f,* tongue; *g,* neck.

in such a way as to leave a third tube between the two. It is through the central tube that the nectar is pumped or sucked up; the two outer tubes Réaumur imagines are for the reception of air: if this be the case, it may possibly be that air which is discharged from the central tube to create the necessary vacuum. The mandibles, or upper jaws, and other parts conspicuous in the caterpillar, are to be found *only* in a rudimentary state in the butterfly,—yet they do *exist.*

with gauze wings. These, as I said, are astonishing processes, and must require, as it should seem, a proportionably artificial apparatus. The hypothesis which appears to me most probable is, that, in the grub, there exist at the same time three animals, one within another, all nourished by the same digestion, and by a communicating circulation, but in different stages of maturity.[23] The latest discoveries made by naturalists seem to favour this supposition. The insect already equipped with wings, is described under the membranes both of the worm and nymph. In some species the proboscis, the antennæ, the limbs, and wings of the fly have be observed to be folded up within the body of the cate pillar, and with such nicety as to occupy a small spa only under the two first wings. This being so, t outermost animal which, besides its own proper characte serves as an integument to the other two, being t farthest advanced, dies, as we suppose, and drops first. The second, the pupa or chrysalis, then offers i self to observation. This also, in its turn, dies; its de and brittle husk falls to pieces, and makes way for t appearance of the fly or moth. Now if this be the cas or indeed whatever explication be adopted, we have prospective contrivance of the most curious kind; v have organizations *three deep*, yet a vascular syste which supplies nutrition, growth, and life to all of the together.

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[23] The following observations do not exactly support the opinion of Dr. Paley. It is more probable that the parts which are to appear in the perfect insect do *not* exist in the larvæ, where there is not much difference between the larva and pupa excepting at the time just previous to its becoming a pupa, at which time the larva is motionless and torpid. The caterpillar of a moth, when about to turn into a pupa, provides for the protection of the latter state, either by surrounding itself with a web, or by some other means. Soon after this is accomplished the caterpillar becomes motionless, or nearly so; it can neither eat nor crawl. At this time, and *not before*, the parts of the pupa are forming within the skin of the caterpillar, which may be easily seen by dissection. When the difference between the larva and the perfect insect is great, this is always the case, and the pupa is passive; but when the difference is not so considerable, the case is different. The larva of a grasshopper scarcely differs from the perfect insect it is to become, except in wanting wings; the pupa differs only in having rudimentary instead of perfect wings; it casts its skin; it is then the perfect insect, excepting that the wings are crippled, and these very rapidly expand. In this latter case it is seen that there is but little difference between the three stages, and the change from the caterpillar to the moth is very great, and takes place only during the torpid state of the former, which state is to allow of its taking place. In the case of the grasshopper, where the changes are but slight, we should imagine but little of this torpidity would be required: and such appears to be the case, for the pupæ of grasshoppers, and allied insects, are always as *active* as either the larva or perfect insect.

VI. Almost all insects are oviparous. Nature kee her butterflies, moths, and caterpillars locked up duri the winter in their egg-state; and we have to admi the various devices to which, if we may so speak, t same nature hath resorted for the *security* of the eg Many insects enclose their eggs in a silken web; othe cover them with a coat of hair torn from their ov bodies; some glue them together; and others, like t moth of the silk-worm, glue them to the leaves up which they are deposited, that they may not be shak off by the wind, or washed away by rain. Some, agai make incisions into leaves, and hide an egg in each i cision; whilst some envelope their eggs with a soft sul stance which forms the first aliment of the young anima and some again make a hole in the earth, and, havi stored it with a quantity of proper food, deposit the eggs in it. In all which we are to observe, that the e pedient depends not so much upon the address of t animal, as upon the physical resources of his const tution.

The art also with which the young insect is *coiled* in the egg presents, where it can be examined, a subje of great curiosity. The insect, furnished with all t *members which* it ought to have is rolled up into a for which seems to contract it into the least possible space; by which contraction, notwithstanding the smallness of the egg, it has room enough in its apartment, and to spare. This folding of the limbs appears to me to indicate a special direction; for if it were merely the effect of compression, the collocation of the parts would be more various than it is. In the same species, I beieve, it is always the same.

These observations belong to the whole insect tribe, or to a great part of them. Other observations are imited to fewer species, but not, perhaps, less important or satisfactory.

I. The organization in the abdomen of the *silkworm* r *spider*, whereby these insects form their *thread*, is as ncontestably mechanical as a wire-drawer's mill. In the body of the silkworm are two bags, remarkable for their

orm, position, and use. They wind round the intestine; when drawn out they are ten inches in length, hough the animal itself be only two. Within these ags is collected a glue; and, communicating with the ags, are two paps or outlets, perforated like a grater y a number of small holes. The glue or gum, being assed through these minute apertures, forms hairs of lmost imperceptible fineness; and these hairs, when oined, compose the silk which we wind off from the one in which the silkworm has wrapped itself up: in he spider, the web is formed from this thread. In oth cases, the extremity of the thread, by means of its dhesive quality, is first attached by the animal to some xternal hold; and the end being now fastened to a oint, the insect, by turning round its body, or by reeding from that point, draws out the thread through he holes above described, by an operation, as hath been served, *exactly similar* to the drawing of wire. The thread, like the wire, is formed by the hole through which it passes. In one respect there is a difference. The wire is the metal unaltered, except in figure. In the animal process the nature of the substance is somewhat changed as well as the form; for, as it exists within the insect, it is a soft, clammy gum or glue. The thread acquires, it is probable, its firmness and tenacity from the action of the air upon its surface in the moment of exposure; and a thread so fine is almost all surface. This property, however, of the paste is part of the contrivance.

The mechanism itself consists of the bags or reservoirs into which the glue is collected, and of the external holes communicating with these bags; and the action of the machine is seen in the forming of a thread, as wire is formed, by forcing the material already prepared through holes of proper dimensions. The secretion is an act too subtile for our discernment, except as we perceive it by the produce. But one thing answers to another; the secretory glands to the quality and consistence required in the secreted substance; the bag to its reception. The outlets and orifices are constructed not merely for relieving the reservoirs of their burden, but for manufacturing the contents into a form and texture of great external use, or rather, indeed, of future necessity, to the life and functions of the insect.

II. Bees, under one character or other, have furnished every naturalist with a set of observations. I shall, in this place, confine myself to one; and that is the *relation* which obtains between the wax and the honey. No person who has inspected a bee-hive can forbear remarking how commodiously the honey is bestowed in the comb, and, amongst other advantages, how effectually the fermentation of the honey is prevented by distributing it into small cells. The fact is, that when the honey is separated from the comb, and put into jars, it runs into fermentation with a much less degree of heat than what takes place in a hive. This may be reckoned a nicety; but, independently of any *nicety in the* matter, I would ask, what could the bee do with the honey if it had not the wax? how, at least, could it store it up for winter? The wax, therefore, answers a purpose with respect to the honey; and the honey constitutes that purpose with respect to the wax. This is the relation between them. But the two substances, though together of the greatest use, and without each other of little, come from a different origin. The bee finds the honey, but makes the wax. The honey is lodged in the nectaria of flowers, and probably undergoes little alteration—is merely collected; whereas the wax is a ductile tenacious paste, made out of a dry powder,[24] not simply by kneading it with a liquid, but by a digestive process in the body of the bee. What account can be rendered of facts so circumstanced, but that the animal, being intended to feed upon honey, was, by a peculiar external configuration, enabled to procure it? That, moreover, wanting the honey when it could not be procured at all, it was further endued with the no less necessary faculty of constructing repositories for its preservation? Which faculty, it is evident, must depend primarily upon the capacity of providing suitable materials. Two distinct functions go to make up the ability. First, the power in the bee, with respect to wax, of loading the farina of flowers upon its thighs. Microscopic observers speak of the spoon-shaped appendages with which the thighs of bees are beset for this very purpose; but, inasmuch as the art and will of the bee may be supposed to be concerned in this operation, there is, secondly, that which doth not rest in art or will—a digestive faculty, which converts the loose powder into a stiff substance. This is a just account of the honey and the honey-comb; and this account, through every part, carries a creative intelligence along with it.[25]

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[24] The opinion of Huber, Hunter, and others, is, that wax is not made out of pollen, but from honey. Huber kept some bees confined, and fed them with honey only, and wax was secreted as usual. It is most likely that bees never eat farina, and that it is collected for the larvæ only. See article BEE, '*Penny Cyclopædia.*'

[25] *It has often been* remarked, that Dr. Paley does not

The *sting* also of the bee has this relation to the honey, that it is necessary for the protection of a treasure which invites so many robbers.

III. Our business is with mechanism. In the *panorpa* tribe of insects, there is a forceps in the tail of the male insect with which he catches and holds the female. Are a pair of pincers more mechanical than this provision in its structure? or is any structure more clear and certain in its design?[26]

IV. St. Pierre tells us,[*] that in a fly with six feet (I do not remember that he describes the species), the pair next the head and the pair next the tail have brushes at their extremities, with which the fly dresses, as there may be occasion, the anterior or the posterior part of its body; but that the middle pair have no such brushes, the situation of these legs not admitting of the brushes, if they were there, being converted to the same use. This is a very exact mechanical distinction.[27]

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either in this chapter, or in that on instinct, state the most remarkable of all instincts, and of all the labours of insects, the formation of the cells by the bee according to the strictest geometrical rules. The history of this discovery made (through Réaumur's suggestion) by Kœnig's application of the fluxional calculus, and by its result being found to tally with Maraldi's measurement, will be given in the Appendix. Maclaurin solved the same problem afterwards by the help of plane geometry, with a truly felicitous skill. The angles actually made differ by about two minutes from those given by the calculus; but no one can doubt that subsequent discovery will explain this.

[26] In the genus *Trichius* (a tribe of beetles closely allied to the rose beetle) the males have the tibiæ of the middle pair of legs curved for the same purpose.

[27] The stag-beetle (*Lucanus cervus*) cleans its antennæ "by drawing them between the thigh of the foreleg and the underside of the thorax, in both of which parts a velvet-like patch of hair is to be observed, which is well adapted for such purpose." See this, and other peculiarities in the same insect, in the first Part of the Entomological Society's Transactions, in 'The Journal of Proceedings,' page 6.

[*] Vol. i. p. 342.

:he reader, looking to our distributions of sci-
ı to contemplate the chemistry as well as the
n of nature, the insect creation will afford him
le. I refer to the light in the tail of a *glow-*
`wo points seem to be agreed upon by naturalists
g it: first, that it is phosphoric; secondly,
e is to attract the male insect. The only thing
ıired after is the singularity, if any such there
natural history of this animal, which should
)rovision of this kind more necessary for it than
insects. That singularity seems to be the dif-
hich subsists between the male and the female,
:erence is greater than what we find in any
:ies of animal whatever. The glow-worm is a
terpillar, the male of which is a *fly*, lively,
vely small, dissimilar to the female in appear-
)ably also as distinguished from her in habits,
and manners, as he is unlike in form and ex-
stitution. Here then is the adversity of the
ıe caterpillar cannot meet her companion in the
winged rover disdains the ground. They
ver therefore be brought together did not this
rch direct the volatile mate to his sedentary

example we also see the resources of art anti-
One grand operation of chemistry is the
'phosphorus; and it was thought an ingenious
make phosphoric matches supply the place of
pers. Now this very thing is done in the body
w-worm. The phosphorus is not only made,

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emale glow-worm undergoes the same transforma-
. other insects, and its perfect state differs con-
'rom its larva or caterpillar state, though in both
mits the phosphoric light. Besides the ordinary
inctions, the female glow-worm differs from the
in being apterous; but apterous female insects are
uent; thus many species of moths have no wings.
ircumstances of the sedentary habits of the female,
ales flying by *night only*, seem to show the use of
See the next note.

but kindled, and caused to emit a steady and g
beam, for the purpose which is here stated, and wh
believe to be the true one.[29]

VI. Nor is the last the only instance that entom
affords, in which our discoveries, or rather our pro
turn out to be imitations of nature. Some years a
plan was suggested of producing propulsion by re-
in this way: by the force of a steam-engine, a st
of water was to be shot out of the stern of a boat
impulse of which stream upon the water in the rive
to push the boat itself forward; it is in truth the
ciple by which sky-rockets ascend in the air. O
use or practicability of the plan I am not speaking
is it my concern to praise its ingenuity; but it is
tainly a contrivance. Now, if naturalists are to b
lieved, it is exactly the device which nature has
use of for the motion of some species of aquatic in
The larva of the *dragon-fly*, according to Adams,
by ejecting water from its tail—is driven forward b
re-action of water in the pool upon the current is
in a direction backward from its body.

VII. Again: Europe has lately been surpris
the elevation of bodies in the air by means of a b
The discovery consisted in finding out a mana
substance, which was, bulk for bulk, lighter th
and the application of the discovery was to make
composed of this substance bear up, along with
weight, some heavier body which was attache
This expedient, so new to us, proves to be no otl
what the Author of nature has employed in the

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[29] There exists some controversy among natura
the use of the glow-worm's light. The doubt
chiefly raised by the observation that the insect is
though in an imperfect degree, when in the state
it cannot propagate, as mentioned in the last note
[illegible]her insects are attracted by light as well as the
[illegible]. The preponderance of the argument is d
[illegible]our of the supposition adopted by our author,
[illegible]only received opinion. The pa
[illegible]ll be given in the Appendix.

spider. We frequently see this spider's thread floating in the air, and extended from hedge to hedge across a road or brook of four or five yards' width. The animal which forms the thread has no wings wherewith to fly from one extremity to the other of this line, nor muscles to enable it to spring or dart to so great a distance: yet its Creator hath laid for it a path in the atmosphere; and after this manner. Though the animal itself be heavier than air, the thread which it spins from its bowels is specifically lighter. This is its *balloon*. The spider, left to itself, would drop to the ground; but being tied to its thread, both are supported. We have here a very peculiar provision; and to a contemplative eye it is a gratifying spectacle to see this insect wafted on her thread, sustained by a levity not her own, and traversing regions which, if we examined only the body of the animal, might seem to have been forbidden to its nature.[30]

I must now crave the reader's permission to introduce into this place, for want of a better, an observation or two upon the tribe of animals, whether belonging to land or water, which are covered by *shells*.

I. The *shells* of *snails* are a wonderful, a mechanical, and, if one might so speak concerning the works of nature, an original contrivance. Other animals have their proper retreats, their hybernacula also, or winter-quarters, but the snail carries these about with him. He travels with his tent; and this tent, though, as was necessary, both light and thin, is completely impervious either to moisture or air. The young snail comes out of its egg with the shell upon its back; and the gradual enlargement which the shell receives is derived from the

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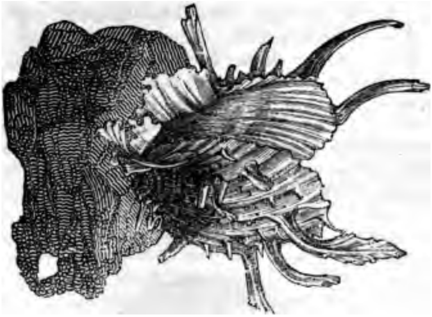
[30] It was at one time supposed that the spider could project its thread through the air at will in any direction, and thus attaching it to different bodies, move from one to the other. The observations more accurately made of late years, show that this power is not possessed by the animal, but that it requires the aid of a current of air to direct the thread. This *correction*, however, of the former opinion, *in no way weakens the force* of the argument in the text.

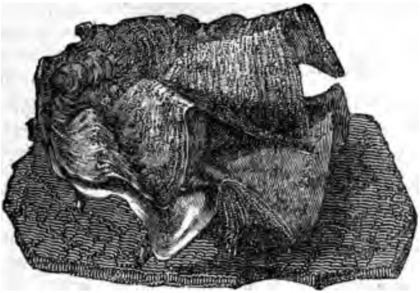
Helix aspersa of Müller,—common garden snail; but the cut represents what is called a left-handed shell, and a rarity.

slime excreted by the animal's skin. Now the aptness of this excretion to the purpose, its property of hardening into a shell, and the action, whatever it be, of the animal, whereby it avails itself of its gift, and of the constitution of its glands (to say nothing of the work being commenced before the animal is born), are things which can, with no probability, be referred to any other cause than to express design; and that not on the part of the animal alone, in which design, though it might build the house, it could not have supplied the material. The will of the animal could not determine the quality of the excretion. Add to which, that the shell of the snail, with its pillar and convolution, is a very artificial fabric; whilst a snail, as it should seem, is the most numb and unprovided of all artificers. In the midst of variety there is likewise a regularity which could hardly be expected. In the same species of snail the number *of turns is usually*, if not always, the same. The sealing of the mouth of the shell by the snail is also well lculated for its warmth and security; but the cerate not of the same substance with the shell.



Spondylus—prickly oyster.

II. Much of what has been observed of snails belongs *shell-fish* and their *shells*, particularly to those of the ivalve kind; with the addition of two remarks—one which is upon the great strength and hardness of most



trea crista galli of Lamarck, Mytilus crista galli of Linnæus—the *s-comb oyster.*

of these shells. I do not know whether, the weight being given, art can produce so strong a case as are some of these shells; which defensive strength suits well with the life of an animal that has often to sustain the dangers of a stormy element and a rocky bottom, as well as the attacks of voracious fish. The other remark is upon the property, in the animal excretion, not only of congealing, but of congealing or, as a builder would call it, *setting*, in water, and into a cretaceous substance, firm and hard. This property is much more extraordinary, and, chemically speaking, more specific, than that of hardening in the air, which may be reckoned a kind of exsiccation, like the drying of clay into bricks.

III. In the *bivalve* order of shell-fish, cockles, muscles, oysters, &c., what contrivance can be so simple or so clear as the insertion, at the back, of a tough tendinous substance that becomes at once the ligament which binds the two shells together, and the *hinge* upon which they open and shut?

Cardium cardissa—Venus' heart cockle.

IV. The shell of a lobster's tail, in its articulations and overlappings, represents the jointed part of a coat of mail; or rather, which I believe to be the truth, a coat of mail is an imitation of a lobster's shell. The same end is to be answered by both; the same properties, therefore, are required in both, namely, hardness and flexibility—a covering which may guard the part with obstructing its motion. For this double purpose the art of man, expressly exercised upon the subject, has not been able to devise anything better than what nature presents to his observation. Is not this therefore mechanism, which the mechanic, having a similar purpose in view, adopts? Is the structure of a coat of mail to be referred to art? Is the same structure of the lobster, conducing to the same use, to be referred to anything less than art?

Some who may acknowledge the imitation, and assent to the inference which we draw from it in the instance before us, may be disposed, possibly, to ask, why such imitations are not more frequent than they are, if it be true, as we allege, that the same principle of intelligence, design, and mechanical contrivance was exerted in the formation of natural bodies as we employ in the making of the various instruments by which our purposes are served? The answers to this question are, first, that it seldom happens that precisely the same purpose, and no other, is pursued in any work which we compare of nature and of art; secondly, that it still more seldom happens that we *can* imitate nature if we would. Our materials and our workmanship are equally deficient. Springs and wires, and cork and leather, produce a poor substitute for an arm or a hand. In the example which we have selected, I mean a lobster's shell compared with a coat of mail, these difficulties stand less in the way than in almost any other that can be assigned; and the consequence is, as we have seen, that art gladly borrows from nature her contrivance, and imitates it closely.

But to return to insects. I think it is in this class of animals above all others, especially when we take in the multitude of species which the microscope discovers, that we are struck with what Cicero has called "the *insatiable* variety of nature." There are said to be six thousand species of flies; seven hundred and sixty butterflies; each different from all the rest (St. Pierre).[31] The

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[31] *There are collections of* insects in this country which,

same writer tells us, from his own observation, tl
thirty-seven species of winged insects, with distinctic
well expressed, visited a single strawberry-plant in t
course of three weeks.* Ray observed, within the co
pass of a mile or two of his own house, two hundı
kinds of butterflies,[32] nocturnal and diurnal. He lil
wise asserts, but, I think, without any grounds of ex
computation, that the number of species of insec
reckoning all sorts of them, may not be short of t
thousand.† And in this vast variety of animal fori
(for the observation is not confined to insects, thou
more applicable perhaps to them than to any other clas
we are sometimes led to take notice of the differe
methods, or rather of the studiously diversified metho
by which one and the same purpose is attained. In t
article of breathing, for example, which was to be pı
vided for in some way or other, besides the ordinary v
rieties of lungs, gills, and breathing-holes (for insects
general respire, not by the mouth, but through holes
the sides), the nymphæ of gnats have an apparatus
raise their *backs* to the top of the water, and so ta
breath. The hydrocanthari do the like by thrusti
their *tails* out of the water.‡ The maggot of the eri
labra has a long tail, one part sheathed within anoth
(but which it can draw out at pleasure), with a stai
tuft at the end, by which *tuft*, when expanded upon t
surface, the insect both supports itself in the water, a

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in all probability, contain forty thousand species. The nu
ber of species in existence may fairly be reckoned at si
or eighty thousand. Mr. Stephens, in his catalogue of B
tish insects, enumerates ten thousand, since the publication
which many new species have been discovered. We are n
speaking of true insects,—animals having six legs, &c.,—a
not including crabs, spiders, scorpions, and others, whi
have been classed with insects.

[32] Ray must mean butterflies and *moths*,—we have not o
hundred species of butterflies in this country; and besid
no butterflies are "nocturnal."

* Vol. i. p. 3. † Wisd. of God, p. 23.

‡ Derham, p. 7.

draws in the air which is necessary. In the article of natural clothing, we have the skins of animals invested with scales, hair, feathers, mucus, froth, or itself turned into a shell or crust. In the no less necessary article of offence and defence, we have teeth, talons, beaks, horns, stings, prickles, with (the most singular expedient for the same purpose) the power of giving the electric shock, and, as is credibly related of some animals, of driving away their pursuers by an intolerable fœtor, or of blackening the water through which they are pursued. The consideration of these appearances might induce us to believe that *variety* itself, distinct from every other reason, was a motive in the mind of the Creator, or with the agents of his will.

To this great variety in organised life the Deity has given, or perhaps there arises out of it, a corresponding variety of animal *appetites*. For the final cause of this we have not far to seek. Did all animals covet the same element, retreat, or food, it is evident how much fewer could be supplied and accommodated than what at present live conveniently together, and find a plentiful subsistence. What one nature rejects another delights in. Food which is nauseous to one tribe of animals becomes, by that very property which makes it nauseous, an alluring dainty to another tribe. Carrion is a treat to dogs, ravens, vultures, fish.[33] The exhalations of corrupted substances attract flies by crowds. Maggots revel in putrefaction.[34]

[33] Very many insects subsist entirely upon carrion, both in the larva and imago state, and in hot weather must be highly serviceable in removing such noxious substances. In this point of view the maggots of flies are exceedingly useful; a carcase becoming speedily threaded in every direction by them, is soon either devoured or wasted.

[34] The most remarkable circumstance relative to instinct, as well as to the habits of insects, the architecture of the bee, has been observed upon in a former note. The manufacture of the wasp perhaps comes next, and is to the chemistry what the former is to the mathematics of instinct. It furnishes, too, one of the most striking instances of the discoveries of

man having been anticipated by the lower animals; a another remarkable proof how many more might have made by closely attending to their habits,—perhaps a remarkable proof than those referred to in the text o chapter, and hinted at in chapter viii., where the auth treating of the vertebræ and ribs. It is certain that so the most material improvements in paper-making rec introduced, as the use of other substances besides rags the obtaining toughness by means of long fibres, had known to the wasp from its first creation. Its whole p in making what is called *wasp-paper* is precisely that c best paper-makers. This will be illustrated in the Appe It is only mentioned here as another among the strikin stances of the Divine agency through the operations o reasoning animals—instances which fill the contemp mind with the most profound and pleasing admiration dispose it to the enjoyment and the duty of heartfel votion.

The migration of birds is another subject full c struction regarding the great questions connected wit stinct, and is reserved for the Appendix. Obser seems at variance with the notion of the older birds t ing the yearlings; indeed, the two classes have been not to travel together. But the agitation universall served in birds of passage kept in cages, at the seas migration, proves clearly that no experience nor instr will account for the change of place. See Mr. W. Her excellent remarks on this instinct, and on the simil stincts respecting choice of food, which makes birds b a cage at once select their appointed food when shown for the first time (White's Selborne, edit. 1833, p. *seq.*) The facts respecting carrier-pigeons and other an finding their way through countries in the knowl which they never could have been trained, belo same class, and will be particularly discussed pendix—Dissertation upon Instinct. The doc flicting instincts will be considered under the flicting contrivances in the Dissertations u adverted to in the Notes on the last chapt parent conflicts afford no ground whatever for argument as to design; and they in no way sceptical argument drawn, and inaccuratel other sources, respecting benevolence.

CHAPTER XX

OF PLANTS.

I THINK a designed and studied mechanism to be in general more evident in animals than in *plants:* and it is unnecessary to dwell upon a weaker argument where a stronger is at hand. There are, however, a few observations upon the vegetable kingdom which lie so directly in our way, that it would be improper to pass by them without notice.

The one great intention of nature in the structure of plants seems to be the perfecting of the *seed*, and, what is part of the same intention, the preserving of it until it be *perfected*. This intention shows itself, in the first place, by the care which appears to be taken to protect and ripen, by every advantage which can be given to them of situation in the plant, those parts which most immediately contribute to fructification, viz., the antheræ, the stamina, and the stigmata. These parts are usually lodged in the centre, the recesses, or the labyrinths of the flower—during their tender and immature state are shut up in the stalk, or sheltered in the bud—as soon as they have acquired firmness of texture sufficient to bear exposure, and are ready to perform the important office which is assigned to them, they are disclosed to the light and air by the bursting of the stem or the expansion of the petals; after which they have, in many cases, by the very form of the flower during its blow, the light and warmth reflected upon them from the concave side of the cup. What is called also the *sleep* of plants is the leaves or petals disposing themselves in such a manner as to shelter the young stems, buds, or fruit. They turn up, *or they fall* down, according as this purpose renders either change of position requisite. In the growth of corn, whenever the plant beg the two upper leaves of the stalk join toge the ear, and protect it till the pulp has a tain degree of consistency. In some wat flowering and fecundation are carried on *wi* which afterwards opens to let loose the seed.* The *pea*, or papilionaceous, trib parts of fructification within a beautiful f internal blossom, sometimes called, fro the boat or keel—itself also protected u house formed by the external petals. T is very artificial; and what adds to the though it may diminish the curiosity, very has also this further advantage (and it is strictly mechanical), that all the blosso *backs* to the wind whenever the gale

Papaver rhœas—Poppy.

enough to endanger the delicate parts up seed depends. I have observed this a hun a field of peas in blossom. It is an aptitu sults from the figure of the flower, and, as is strictly mechanical, as much so as the turning of a weather-board or tin cap upon the top of a chimney. Of the *poppy*, and of many similar species of flowers, the head while it is growing hangs down, a rigid curvature in the upper part of the stem giving to it that position; and in that position it is impenetrable by rain or moisture. When the head has acquired its size and is ready to open, the stalk *erects* itself for the purpose, as it should seem, of presenting the flower, and with the flower the instruments of fructification, to the genial influence of the sun's rays. This always struck me as a curious property, and specifically as well as originally provided for in the constitution of the plant; for if the stem be only bent by the weight of the head, how comes it to straighten itself when the head is the heaviest? These instances show the attention of nature to this principal object, the safety and maturation of the parts upon which the seed depends.

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* Philos. Transact., part ii. 1796, p

In *trees*, especially in those which are natives of colder climates, this point is taken up earlier. Many of these trees (observe in particular the *ash* and the *horse-chestnut*) produce the embryos of the leaves and flowers in one year, and bring them to perfection the following. There is a winter therefore to be gotten over. Now what we are to remark is, how nature has prepared for the trials and severities of that season. These tender embryos are, in the first place, wrapped up with a compactness which no art can imitate; in which state they compose what we call the bud. This is not all. The bud itself is enclosed in scales; which scales are formed from the remains of past leaves, and the rudiments of future ones.[35]

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[35] This is not exactly true. Buds are not enclosed in scales formed from the remains of past leaves, except in a few rare instances, to which it cannot be supposed that the author refers; neither are they protected by what can correctly be called the rudiments of future leaves, or are only protected in part. The extensive scales of a bud, those in which the office of protection more especially resides, are rudimentary leaves, *which* are formed at the end of the *season, when the force of* development in the vegetable sys-

Neither is this the whole. In the coldest clima third preservative is added, by the bud having a ca gum or resin, which, being congealed, resists the str est frosts. On the approach of warm weather this is softened, and ceases to be a hindrance to the expan of the leaves and flowers. All this care is part of system of provisions which has for its object and summation the production and perfecting of the seed

The SEEDS themselves are packed up in a capsu vessel composed of coats, which, compared with the of the flower, are strong and tough. From this ve projects a tube, through which tube the farina, or s subtile fecundating effluvium that issues from it, is mitted to the seed. And here also occurs a mechar variety, accommodated to the different circumsta under which the same purpose is to be accomplis In flowers which are erect, the pistil is shorter than stamina; and the pollen, shed from the antheræ into cup of the flower, is caught in its descent by the h of the pistil, called the stigma. But how is this mana when the flowers hang down (as does the crown-perial for instance), and in which position, the far in its fall, would be carried from the stigma, and towards it? The relative length of the parts is inverted. The pistil in these flowers is usually lon instead of shorter, than the stamina, that its protrud summit may receive the pollen as it drops to the grou In some cases (as in the *nigella*), where the shaft the pistils or stiles are disproportionably long, they b down their extremities upon the antheræ, that the cessary approximation may be effected.

But (to pursue this great work in its progress), impregnation, to which all this machinery relates, be completed, the other parts of the flower fade and d off, whilst the *gravid seed-vessel*, on the contrary, ceeds to increase its bulk, always to a great, and

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tem is weak and imperfect; they do not become le another season, but are simply thrown off by the expan *of the leaves* which unfold from within them.

some species (in the gourd, for example, and melon), to a surprising comparative size; assuming in different plants an incalculable variety of forms, but all evidently conducing to the security of the seed. By virtue of this process, so necessary, but so diversified, we have the seed at length, in stone-fruits and nuts, incased in a strong shell, the shell itself enclosed in a pulp or husk, by which the seed within is, or hath been, fed; or, more generally (as in grapes, oranges, and the numerous kinds of berries), plunged overhead in a glutinous syrup, contained within a skin or bladder: at other times (as in apples and pears) embedded in the heart of a firm fleshy substance; or (as in strawberries) pricked into the surface of a soft pulp.

These and many more varieties exist in what we call *fruits.*[*] In pulse, and grain, and grasses; in trees, and

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[*] From the conformation of fruits alone, one might be led, even without experience, to suppose that part of this provision was destined for the utilities of animals. As limited to the plant, the provision itself seems to go beyond its object. The flesh of an apple, the pulp of an orange, the meat of a plum, the fatness of the olive, appear to be *more* than sufficient for the nourishing of the seed or kernel. The event shows that this redundancy, if it be one, ministers to the support and gratification of animal natures; and when we observe a provision to be more than sufficient for one purpose, yet wanted for another purpose, it is not unfair to conclude that both purposes were contemplated together. It favours this view of the subject to remark, that fruits are not (which they might have been) ready altogether, but that they ripen in succession throughout a great part of the year; some in summer; some in autumn; that some require the slow maturation of the winter, and supply the spring; also that the coldest fruits grow in the hottest places. Cucumbers, pine-apples, melons, are the natural produce of warm climates, and contribute greatly, by their coolness, to the refreshment of the inhabitants of those countries.

I will add to this note the following observation communicated to me by Mr. Brinkley

"The eatable part of the cherry or peach first serves the purposes *of perfecting the* seed or kernel, by means of vessels *passing through the stone,* and which are very visible in a shrubs, and flowers; the variety of the seed-vessels is incomputable. We have the seeds (as in the pea tribe) regularly disposed in parchment pods, which, though soft and membranous, completely exclude the wet even in the heaviest rains; the pod also, not seldom (as in the bean), lined with a fine down; at other times (as in the senna) distended like a blown bladder: or we have the seed enveloped in wool (as in the cotton plant), lodged (as in pines) between the hard and compact scales of a cone, or barricadoed (as in the artichoke and thistle) with spikes and prickles; in mushrooms, placed under a pent-house; in ferns, within slits in the back part of the leaf: or (which is the most general organization of all) we find them covered by strong, close tunicles, and attached to the stem according to an order appropriated to each plant, as is seen in the several kinds of grains and of grasses.

In which enumeration, what we have first to notice is, unity of purpose under variety of expedients. Nothing can be more *single* than the design; more *diversified* than the means. Pellicles, shells, pulps, pods, husks, skin, scales armed with thorns, are all employed in prosecuting the same intention. Secondly; we may observe, that, in all these cases, the purpose is fulfilled within a just and *limited* degree. We can perceive, that if the seeds of plants were more strongly guarded than they are, their greater security would interfere with other uses. Many species of animals would suffer, and many perish, if they could not obtain access to them. The plant would overrun the soil; or the seed be wasted

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peach-stone. After the kernel is perfected, the stone becomes hard, and the vessels cease their functions. But the substance surrounding the stone is not then thrown away as useless. That which was before only an instrument for perfecting the kernel, now receives and retains to itself the whole of the sun's influence, and thereby becomes a grateful food to man. Also what an evident mark of design is the stone protecting the kernel! The intervention of the stone prevents the second use from interfering with the first."—*Note of the Author.*

want of room to sow itself. It is sometimes as neces- y to destroy particular species of plants, as it is, at ier times, to encourage their growth. Here, as in ny cases, a balance is to be maintained between op- site uses. The provisions for the preservation of ds appear to be directed chiefly against the incon- ncy of the elements, or the sweeping destruction of lement seasons. The depredation of animals, and the uries of accidental violence, are allowed for in the ındance of the increase. The result is, that out of the ny thousand different plants which cover the earth, t a single species, perhaps, has been lost since the ation.

When nature has perfected her seeds, her next care to disperse them. The seed cannot answer its pur- se while it remains confined in the capsule. After seeds therefore are ripened, the pericarpium opens let them out; and the opening is not like an accidental rsting, but, for the most part, is according to a certain e in each plant. What I have always thought very traordinary, nuts and shells, which we can hardly ck with our teeth, divide and make way for the little der sprout, which proceeds from the kernel. Hand- g the nut, I could hardly conceive how the plantule s ever to get out of it. There are cases, it is said, in ich the seed-vessel, by an elastic jerk, at the moment its explosion, casts the seeds to a distance. We all wever know, that many seeds (those of most composite wers, as of the thistle, dandelion, &c.) are endowed th what are not improperly called *wings*; that is, wny appendages, by which they are enabled to float in air, and are carried oftentimes by the wind to great tances from the plant which produces them. It is the elling also of this downy tuft within the seed-vessel it seems to overcome the resistance of its coats, and open a passage for the seed to escape.

But the *constitution* of seeds is still more admirable n either their preservation or their dispersion. In body of the seed of every species of plant, or nearly *every one, provision* is made for two grand purposes:

first, for the safety of the *germ;* secondly, for the temporary support of the future plant. The sprout, as folded up in the seed, is delicate and brittle beyond any other substance. It cannot be touched without being broken. Yet, in beans, peas, grass-seeds, grain, fruits, it is so fenced on all sides, so shut up and protected, that, whilst the seed itself is rudely handled, tossed into sacks, shovelled into heaps, the sacred particle, the miniature plant, remains unhurt. It is wonderful how long many kinds of seeds, by the help of their integuments, and perhaps of their oils, stand out against decay. A grain of mustard-seed has been known to lie in the earth for a hundred years; and, as soon as it had acquired a favourable situation, to shoot as vigorously as if just gathered from the plant. Then, as to the second point, the temporary support of the future plant, the matter stands thus. In grain, and pulse, and kernels, and pippins, the germ composes a very small part of the seed. The rest consists of a nutritious substance, from which the sprout draws its aliment for some considerable time after it is put forth; viz., until the fibres, shot out from the other end of the seed, are able to imbibe juices from the earth, in a sufficient quantity for its demand. It is owing to this constitution, that we see seeds sprout, and the sprouts make a considerable progress, without any earth at all. It is an economy, also, in which we remark a close analogy between the seeds of plants and the eggs of animals. The same point is provided for, in the same manner, in both. In the egg, the residence of the living principle, the cicatrix, forms a very minute part of the contents. The white and the white only is expended in the formation of the chicken. The yolk, very little altered or diminished, is wrapped up in the abdomen of the young bird, when it quits the shell; and serves for its nourishment, till it have learnt to pick its own food. This perfectly resembles the first nutrition of a plant. In the plant, as well as in the animal, the structure has every character of contrivance belonging to it: in both it breaks the transition from *prepared* to *unprepared* aliment; in both, it is prospec-

nd compensatory. In animals which suck, this
ediate nourishment is supplied by a different

.ll subjects, the most common observations are the
when it is their truth and strength which have
:hem common. There are, of this sort, *two* con-
g plants, which it falls within our plan to notice.
irst relates to, what has already been touched
their germination. When a grain of corn is cast
e ground, this is the change which takes place.
one end of the grain issues a green sprout; from
ıer, a number of white fibrous threads. How can
explained? Why not sprouts from both ends?
ot fibrous threads from both ends? To what is
fference to be referred, but to design; to the
nt uses which the parts are thereafter to serve;
hich discover themselves in the sequel of the pro-
The sprout, or plumule, struggles into the air;
comes the plant, of which, from the first, it con-
the rudiments: the fibres shoot into the earth;
ereby both fix the plant to the ground, and collect
ıment from the soil for its support. Now, what
a little remarkable, the parts issuing from the seed
ıeir respective directions, into whatever position
ed itself happens to be cast. If the seed be
ı into the wrongest possible position; that is, if
ds point in the ground the reverse of what they
to do, every thing, nevertheless, goes on right.
prout, after being pushed down a little way, makes
, and turns upwards; the fibres, on the contrary,
hooting at first upwards, turn down. Of this ex-
nary vegetable fact, an account has lately been
ted to be given. "The plumule (it is said) is
ted by the *air* into action, and elongates itself
t is thus most excited; the radicle is stimulated
sture, and elongates itself when *it* is thus most
l. Whence one of these grows upward in quest
dapted object, and the other downward."* Were

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* *Darwin's Phytologia*, p. 144.

this account better verified by experiment than it is, it only shifts the contrivance. It does not disprove the contrivance; it only removes it a little farther back. Who, to use our author's own language, "*adapted the* objects?" Who gave such a quality to these connate parts, as to be susceptible of *different* "stimulation;" as to be "excited" each only by its own element, and precisely by that which the success of the vegetation requires? I say, "which the success of the vegetation requires:" for the toil of the husbandman would have been in vain, his laborious and expensive preparation of the ground in vain; if the event must, after all, depend upon the position in which the scattered seed was sown. Not one seed out of a hundred would fall in a right direction.

Our *second* observation is upon a general property of climbing plants, which is strictly mechanical. In these plants, from each knot or joint, or, as botanists call it, axilla, of the plant, issue, close to each other, two shoots, one bearing the flower and fruit, the other drawn out into a wire, a long, tapering, spiral tendril, that twists itself round anything which lies within its reach. Considering that in this class two purposes are to be provided for (and together), fructification and support, the fruitage of the plant and the sustentation of the stalk, what means could be used more effectual, or, as I have said, more mechanical, than what this structure presents to our eyes? Why, or how, without a view to this double purpose, do two shoots, of such different and appropriate forms, spring from the same joint, from contiguous points of the same stalk? It never happens thus in robust plants, or in trees. "We see not," says Ray, "so much as one tree, or shrub, or herb, that hath a firm and strong stem, and that is able to mount up and stand alone without assistance, *furnished with these tendrils.*" Make only so simple a comparison as that between a pea and a bean. Why does the pea put forth tendrils, the bean not? but because the stalk of the pea cannot support itself, the stalk of the bean can. We may add also, as a circumstance not to be over-

that, in the pea tribe, these clasps do not make
ıpearance till they are wanted—till the plant has
:o a height to stand in need of support.
word "support" suggests to us a reflection upon
rty of grasses, of corn, and canes. The hollow
: these classes of plants are set at certain inter-
th joints. These joints are not found in the
ıf trees, or in the solid stalks of plants. There
other uses of these joints; but the fact is, and it
to be at least one purpose designed by them,
y *corroborate* the stem, which by its length and
ess would otherwise be too liable to break or

ıes are Nature's care. With these she clothes
h—with these she sustains its inhabitants. Cattle
m their leaves—birds upon their smaller seeds—
on the larger; for few readers need be told that
ts which produce our bread corn belong to this
In those tribes which are more generally con-
ıs grasses, their extraordinary means and powers
rvation and increase, their hardiness, their almost
ıerable disposition to spread, their faculties of
ınce, coincide with the intention of Nature con-
them. They thrive under a treatment by which
ants are destroyed. The more their leaves are
ıd, the more their roots increase. The more they
ıpled upon, the thicker they grow. Many of the
ly dry and dead leaves of grasses revive, and
ıeir verdure in the spring.[36] In lofty mountains,
he summer heats are not sufficient to ripen the
;rasses abound which are viviparous, and conse-
able to propagate themselves without seed. It
servation likewise which has often been made,
bivorous animals attach themselves to the leaves
es, and if at liberty in their pastures to range

e, to be correct, we should read "Many grasses whose
·e so dry and withered that the plants appear dead,
nd renew their existence in the spring by pushing
w leaves from the bosom of the former ones."

and choose, leave untouched the straws which support the flowers.*

The GENERAL properties of vegetable nature, or properties common to large portions of that kingdom, are almost all which the compass of our argument allows us to bring forward. It is impossible to follow plants into their several species. We may be allowed, however, to single out three or four of these species as worthy of a particular notice, either by some singular mechanism, or by some peculiar provision, or by both.

I. In Dr. Darwin's 'Botanic Garden' (l. 395, note) is the following account of the *vallisneria*, as it has been observed in the river Rhone:—"They have roots at the bottom of the Rhone. The flowers of the *female plant* float on the surface of the water, and are furnished with an *elastic spiral stalk*, which extends or contracts as the water rises or falls—this rise or fall, from the torrents which flow into the river, often amounting to many feet in a few hours. The flowers of the *male plant* are produced under water; and as soon as the fecundating farina is mature, they separate themselves from the plant, rise to the surface, and are wafted by the air, or borne by the currents, to the female flowers." Our attention in this narrative will be directed to two particulars: first, to the mechanism, the "elastic spiral stalk," which lengthens or contracts itself according as the water rises or falls: secondly, to the provision which is made for bringing the male flower, which is produced *under* water, to the female flower, which floats upon the surface.

II. My second example I take from Withering's 'Arrangement,' vol. ii. p. 209, ed. 3. "The *Cuscuta Europæa* is a parasitical plant. The seed opens, and puts forth a *little spiral body*, which does *not* seek the earth to take root, but *climbs* in a spiral direction, from right to left, up other plants, from which, by means of vessels, it draws its nourishment." The "little spiral body" proceeding from the seed is to be compared with the fibres which seeds send out in ordinary cases; and the

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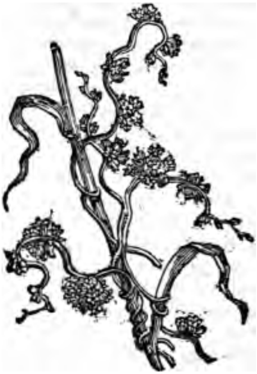
* Withering, Bot. Arr., vol. i. p. 28, ed. 2nd.



ı ought to regard both the form of the threads
irection. They are straight; this is spiral.
t downwards; this points upwards. In the
the exception we equally perceive design.[87]

atement is incorrect. When the seed of cuscuta
ıts forth a little thread-shaped body, namely, a
which, as in other plants, plunges into the earth,
he opposite end elevates a young and slender
latter, after a little while, applies itself to some
ıg plant, and emits very short broad suckers on
ts stem, which is placed in contact with the other
hese suckers it fastens itself upon the new branch,
h it twines, and as soon as it is secure in its new
oot perishes, and it ceases to have any communi-
the earth. This property in the cuscuta seems
it in consequence of its root not having the power
arts usually possess of branching, lengthening,
ing nutriment from the earth. If the cuscuta
nates at a distance from any living branch to
n adhere, it elevates its stem for a short time in
then dies. If it is so placed as to be able to come
nly with dead branches, still it dies; and it is only
eeds in fixing itself upon a living branch that it

III. A better known parasitical plant is the evergreen shrub, called the *misseltoe*. What we have to remark in it is a singular instance of *compensation*. No art hath yet made these plants take root in the earth. Here, therefore, might seem to be a mortal defect in their constitution. Let us examine how this defect is made up to them. The seeds are endued with an adhesive quality so tenacious, that, if they be rubbed upon the smooth bark of almost any tree, they will stick to it. And then what follows? Roots, springing from these seeds, insinuate their fibres into the woody substance of the tree; and the event is, that a misseltoe plant is produced next winter.* Of no other plant do the roots refuse to shoot in the ground; of no other plant do the seeds possess this adhesive, generative quality, when applied to the bark of trees.[38]

IV. Another instance of the *compensatory* system is in the autumnal crocus, or meadow saffron (*colchicum autumnale*). I have pitied this poor plant a thousand times. Its blossom rises out of the ground in the most forlorn condition possible; without a sheath, a fence, a calyx, or even a leaf to protect it: and that, not in the spring not to be visited by summer suns, but under all the disadvantages of the declining year. When we come, however, to look more closely into the structure of this plant, we find that, instead of its being neglected, Nature has gone out of her course to provide for its security, and to make up to it for all its defects. The seed-vessel, which in other plants is situated within the cup of the flower, or just beneath it, in this plant lies

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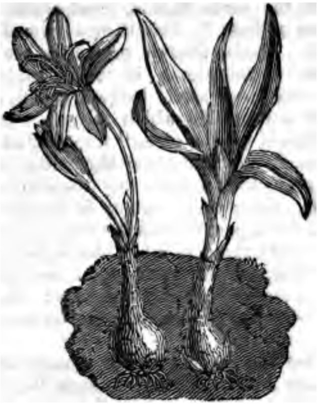
emits its suckers and continues to exist. Once attached to the living stem of another plant, it takes that for its base, and turning round once or twice, then darts forth in a straight line, touches something else which it also fixes in its folds, and thus travels from plant to plant, sometimes covering a very considerable extent of bushes.

[38] These statements are true, not only of the misseltoe or *viscum actum*, but of the whole natural order *Loranthaceæ*, with one exception.

* Withering, Bot. Arr., vol. i. p. 203, ed. 2nd.



ied ten or twelve inches underground within the
bous root. The tube of the flower, which is seldom
re than a few tenths of an inch long, in this plant ex-
ds down to the root. The styles in all cases reach
seed-vessel; but it is in this by an elongation un-
wn to any other plant. All these singularities con-
ute to one end. "As this plant blossoms late in the
r, and probably would not have time to ripen its seeds
ore the access of winter, which would destroy them,
vidence has contrived its structure such, that this
ortant office may be performed at a depth in the earth
of reach of the usual effects of frost."* That is to
, in the autumn nothing is done above ground but
business of impregnation; which is an affair between
antheræ and the stigmata, and is probably soon over.
e maturation of the impregnated seed, which in other
nts proceeds within a capsule, exposed together with
rest of the flower to the open air, is here carried on,
during the whole winter, within the heart, as we

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* *Withering, ubi supra*, p. 360.

may say, of the earth, that is, "out of the reach usual effects of frost." But then a new difficult sents itself. Seeds, though perfected, are know to vegetate at this depth in the earth. Our therefore, though so safely lodged, would, after a lost to the purpose for which all seeds are inte Lest this should be the case, "a second admirabl vision is made to raise them above the surface they are perfected, and to sow them at a prope tance:" viz., the germ grows up *in the spring*, u fruit-stalk, accompanied with leaves. The seeds in common with those of other plants, have the b of the summer, and are sown upon the surface. order of vegetation externally is this:—the plan duces its flowers in September; its leaves and fr the spring following.

V. I give the account of the *dionæa muscipu* extraordinary American plant, as some late author related it: but whether we be yet enough acqu with the plant to bring every part of this acco the test of repeated and familiar observation, I a able to say. "Its leaves are jointed, and furnishe two rows of strong prickles; their surfaces covere a number of minute glands, which secrete a liquor that allures the approach of flies. When parts are touched by the legs of flies, the two lo the leaf instantly spring up, the rows of prickle themselves fast together, and squeeze the unwary to death."* Here, under a new model, we rec the ancient plan of nature, viz., the relation of par provisions to one another, to a common office, and utility of the organized body to which they b The attracting syrup,[39] the rows of strong prickles position so as to interlock the joints of the leaves what is more than the rest, that singular irritabi their surfaces, by which they close at a touch; all bear a contributory part in producing an effect, connected either with the defence or with the nutrition of the plant.[40]

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[39] From this account must be omitted what is said syrup that allures the approach of flies. There is nc attraction upon the leaves of the dionæa.

* Smellie's Phil. of Nat. Hist., vol. i. p. 5.

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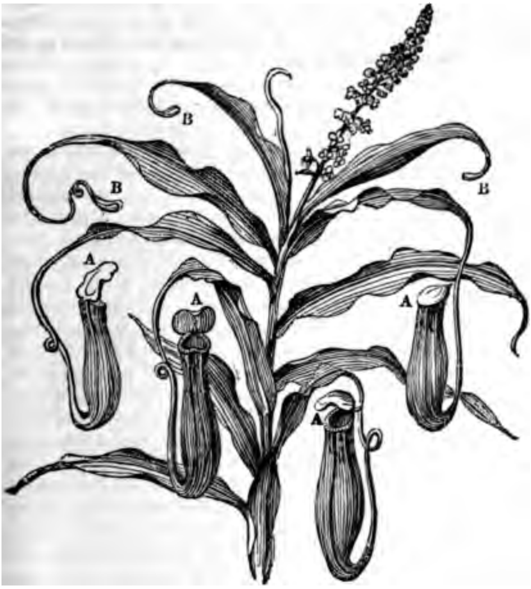
[40] The pitcher-plant, *nepenthes distillatoria*, of the East, is another example which may be given. It grows natural pitchers or tankards, holding from a pint to a quart of pure water. Even when raised in this country under glass, they have been known to hold half-a-pint. The plate represents these, with their lids AA, which move on hi opening in moist weather, and shutting quite close in d prevent evaporation. *When the pitcher becomes* ful *requires additional support,* the hook A behind the lid



[illegible] [illegible], and [illegible] by it. BB ar
just [illegible]. This water which supplie
secreted by the process of vegetation, and i
though the plant grows in a muddy and u
[illegible]

a vaca, or cow-tree of South America, yields
nutritive milk on its trunk being pierced; and
the most parched soil, and in a climate wher
[illegible] during half the year.

ty of fine water afforded by the *tillandsia*
in Jamaica, and by the bejuco or *cissus latifol*
, or [illegible], is a fact of the same class. Th
: also twines round other trees, and affords, as
ervoir for their use.

CHAPTER XXI.

THE ELEMENTS.

EN we come to the elements, we take leave of our
anics; because we come to those things, of the
nization of which, if they be organized, we are con-
dly ignorant. This ignorance is implied by their
:. To say the truth, our investigations are stopped
before we arrive at this point. But then it is for
omfort to find, that a knowledge of the constitution
e elements is not necessary for us. For instance,
ddison has well observed, "we know *water* suffi-
ly, when we know how to boil, how to freeze, how
aporate, how to make it fresh, how to make it run
out out, in what quantity and direction we please,
ut knowing what water is." The observation of
cellent writer has more propriety in it now, than
at the time it was made; for the constitution
e constituent parts of water appear in some mea-
have been lately discovered; yet it does not, I
ppear, that we can make any better or greater
ater since the discovery than we did before it.

n never think of the elements, without reflecting
number of distinct uses which are *consolidated*
me substance. The *air* supplies the lungs,
ire, conveys sound, reflects light, diffuses smells,
, wafts ships, bears up birds. Ἐξ ὕδατος τα
ter, besides maintaining its own inhabitants, is
al nourisher of plants, and through them of
nimals; is the basis of their juices and fluids;
r food; quenches their thirst; floats their
ire warms, dissolves, enlightens: is the great
vegetation and life, if not necessary to the
h.

We might enlarge, to almost any length we please, upon each of these uses; but it appears to me almost sufficient to state them. The few remarks, which I judge it necessary to add, are as follow:—

I. Air is essentially different from earth. There appears to be no necessity for an atmosphere's investing our globe; yet it does invest it: and we see how many, how various, and how important are the purposes which it answers to every order of animated, not to say of organized, beings, which are placed upon the terrestrial surface. I think that every one of these uses will be understood upon the first mention of them, except it be that of *reflecting* light, which may be explained thus:—If I had the power of seeing only by means of rays coming directly from the sun, whenever I turned my back upon the luminary, I should find myself in darkness. If I had the power of seeing by reflected light, yet by means only of light reflected from solid masses, these masses would shine indeed, and glisten, but it would be in the dark. The hemisphere, the sky, the world, could only be *illuminated*, as it is illuminated, by the light of the sun being from all sides, and in every direction, reflected to the eye, by particles, as numerous, as thickly scattered, and as widely diffused, as are those of the air.

Another general quality of the atmosphere is the power of evaporating fluids. The adjustment of this quality to our use is seen in its action upon the sea. In the sea, water and salt are mixed together most intimately; yet the atmosphere raises the water, and leaves the salt. Pure and fresh as drops of rain descend, they are collected from brine. If evaporation be solution (which seems to be probable), then the air dissolves the water, and not the salt. Upon whatever it be founded, the distinction is critical: so much so, that when we attempt imitate the process by art, we must regulate our distill tion with great care and nicety, or, together with t water, we get the bitterness, or at least the distast ness, of the marine substance;—and, after all, it is he separation which we wish, by any art or means 'er.

ɜvaporation, water is carried up into the air: by ıverse of evaporation, it falls down upon the earth. ow does it fall? Not by the clouds being all at 'e-converted into water, and descending like a not in rushing down in columns from a spout; moderate drops, as from a colander. Our water- ; are made to imitate showers of rain. Yet, à I should have thought either of the two former ls more likely to have taken place than the last.

respiration, flame, putrefaction, air is rendered or the support of animal life. By the constant on of these corrupting principles, the whole here, if there were no restoring causes, would t length to be deprived of its necessary degree ty. Some of these causes seem to have been dis- l, and their efficacy ascertained by experiment; far as the discovery has proceeded, it opens to us tiful and a wonderful economy. *Vegetation* proves ne of them. A sprig of mint, corked up with a ortion of foul air, placed in the light, renders it apable of supporting light or flame. Here, there- ; a constant circulation of benefits maintained be- the two great provinces of organized nature. The urifies what the animal has poisoned; in return, ıtaminated air is more than ordinarily nutritious to nt.[41] *Agitation with water* turns out to be ano-

he experiments of Priestley, confirmed by those of ouz and Saussure, led to the conclusion that the air is re by the action of plants, these emitting more oxygen day than carbonic acid gas by night. Some doubt 'own upon this point by the experiments of Mr. Ellis; se appear to have been removed by Sir H. Davy's s and experiments. It seems probable that the plant, ʒ in the light, decomposes both the carbonic acid exists, though in a very small proportion, in the at- re, and also any that may exist in the water applied eaves; for Sennebier found that when these are ed in water impregnated with carbonic acid, oxygen ther of these restoratives. The foulest air bottle with water for a sufficient length of ti

gas was evolved, but not if water was used wl boiled.

The process of vegetation appears to be the g supplying the loss of oxygen in the atmospl none other have been as yet discovered. Th of the atmosphere, in respect of purity, thoug supposed to vary in different places, is now asc everywhere invariably the same. It contains a of oxygen gas, by measure, in 100, and the rem almost entirely nitrogen gas. The only varia slight portion of carbonic acid gas, which never 100, and is seldom more than 1 in 1000, supp culation of the air to be unconfined. But the oxygen to the whole bulk has been found to be nearly 22,000 feet high, and in the deepest same in countries widely remote from each o fering in climate as well as soil; the same in th lential marshes, or in hospitals, and in the m healthy situations. The agitation of the a speedily mixes all its strata, and prevents t breathing and burning from being perceived. stant consumption of oxygen is going on, where either living creatures of the hot-blooded cla any kind, natural or artificial; and this is so the process of vegetation, that the uniformity composition is maintained universally.

The union in which the oxygenous and nitr tions of the atmosphere exist, also merits att ascertained to be of a peculiar kind; for it that of mechanical admixture—the union of a inasmuch as the nitrogen gas, being about a lighter than the oxygen, would rise to the top, the air of higher elevations more pure, contra Nor is it like most other chemical unions, inas both extremely feeble, and is formed without ar in the bulk of the two substances combined to the kind of union in which the two gases ar ductive of the most beneficial effects. Their d from each other is so easily accomplished, tha greatest facility in supporting flame and respi

great degree of its purity.[42] Here then again, allowi
or the scale upon which nature works, we see the sal
ary effects of *storms* and *tempests*. The yesty wave
which confound the heaven and the sea, are doing th
ery thing which was done in the bottle. Nothing can
e of greater importance to the living creation, than the
lubrity of their atmosphere. It ought to reconcile us,
herefore, to the agitations of these elements, of which we
ometimes deplore the consequences, to know that they
end powerfully to restore to the air that purity which
o many causes are constantly impairing.

II. In Water, what ought not a little to be admired,
re those negative qualities which constitute its *purity*.
Iad it been vinous, or oleaginous, or acid; had the sea
een filled, or the rivers flowed, with wine or milk, fish,
onstituted as they are, must have died; plants, consti-
ted as they are, would have withered; the lives of
nimals which feed upon plants must have perished. Its
ery *insipidity*, which is one of those negative qualities,
nders it the best of all menstrua. Having no taste of
own, it becomes the sincere vehicle of every other.
d there been a taste in water, be it what it might, it
uld have infected every thing we ate or drank, with
importunate repetition of the same flavour.

nother thing in this element, not less to be admired,
e constant *round* which it travels; and by which,
out suffering either adulteration or waste, it is con-

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mixture is so perfect, that the mischiefs are prevented
would arise from their being exhibited either to the
r to heated bodies in their pure state.

at agitation with water will remove certain impurities
ir is undeniable, but not all impurities. Animals by
g consume the oxygen, leaving carbonic acid gas
gen gas. Water absorbs the former easily, and bulk
but of the latter it will only absorb 1½ per cent.
products of putrefaction, (beside carbonic acid,)
d hydrogen, and sulphuretted hydrogen gases,
absorb of the latter bulk for bulk, but not above
of the former.

tinually offering itself to the wants of the habitable globe. From the sea are exhaled those vapours which form the clouds: these clouds descend in showers, which, penetrating into the crevices of the hills, supply springs; which springs flow in little streams into the valleys; and there uniting, become rivers; which rivers, in return, feed the ocean. So there is an incessant circulation of the same fluid; and not one drop probably more or less now than there was at the creation. A particle of water takes its departure from the surface of the sea, in order to fulfil certain important offices to the earth; and having executed the service which was assigned to it, returns to the bosom which it left.

Some have thought that we have too much water upon the globe, the sea occupying above three-quarters of the whole surface. But the expanse of ocean, immense as it is, may be no more than sufficient to fertilize the earth. Or, independently of this reason, I know not why the sea may not have as good a right to its place as the land. It may proportionably support as many inhabitants; minister to as large an aggregate of enjoyment. The land only affords a habitable surface; the sea is habitable to a great depth.

III. Of Fire, we have said that it *dissolves*. The only idea probably which this term raised in the reader's mind, was that of fire melting metals, resins, and some other substances, fluxing ores, running glass, and assisting us in many of our operations, chemical or culinary. Now these are only uses of an occasional kind, and give us a very imperfect notion of what fire does for us. The grand importance of this dissolving power, the great office indeed of fire in the economy of nature, is keeping things in a state of solution—that is to say, in a state of fluidity. Were it not for the presence of heat, or of a certain degree of it, all fluids would be frozen. The ocean itself would be a quarry of ice; universal nature stiff and dead.

We see, therefore, that the elements bear not only a strict relation to the constitution of organized bodies, but

tion to each other. Water could not perform
to the earth without air ; nor exist, as water, wi
e.[43]

. Of Light (whether we regard it as of the san
nce with fire, or as a different substance), it
ther superfluous to expatiate upon the use. N
disputes it. The observations, therefore, which
offer, respect that little which we seem to know o
nstitution.

ht travels from the sun at the rate of twelve mil-
of miles in a minute. Urged by such a velocity,
what *force* must its particles drive against (I will
y the eye, the tenderest of animal substances, but)
substance, animate or inanimate, which stands in
y! It might seem to be a force sufficient to shatter
ms the hardest bodies.

w then is this effect, the consequence of such pro-
s velocity, guarded against? By a proportionable
eness of the particles of which light is composed.
impossible for the human mind to imagine to itself
ing so small as a particle of light. But this ex-
exility, though difficult to conceive, it is easy to
A drop of tallow, expended in the wick of a

---

e conducting powers of different substances are beau-
dapted to the wants of the animal and vegetable
. Snow is so bad a conductor, that it protects the
ffectually in rigorous climates. It is said that in
ere have been known to be as many as 38 degrees
eit) of difference between the temperature of the
hat of the ground under the snow; the latter not
ed much below the freezing point. So, too, the
ich, transported to warmer climates, becomes
th hair, has in its own cold country a woolly
d this conducts heat so slowly as to accumulate
espiration is continually producing.
liarity which distinguishes water from other
zing, likewise merits attention. It expands,
tinuing to contract, when cooled to the freezing
is has the useful effect of crumbling earth and
as to *render them* fit for assisting the process

farthing candle, shall send forth rays sufficient hemisphere of a mile diameter; and to fill it so these rays, that an aperture not larger than the p an eye, wherever it be placed within the hemi shall be sure to receive some of them. What fl light are continually poured from the sun, we estimate; but the immensity of the sphere which with particles, even if it reached no farther than th of the earth, we can in some sort compute; and v reason to believe, that, throughout this whole regi particles of light lie, in latitude at least, near to o ther. The spissitude of the sun's rays at the e such, that the number which falls upon a burnin of an inch diameter, is sufficient, when concentra set wood on fire.

The tenuity and the velocity of particles of li ascertained by separate observations, may be sai proportioned to each other, both surpassing our stretch of comprehension; but proportioned. A this proportion alone which converts a tremendo ment into a welcome visiter.

It has been observed to me by a learned frie having often struck his mind, that, if light ha made by a common artist, it would have been uniform *colour:* whereas, by its present compositi have that variety of colours which is of such infin to us for the distinguishing of objects; which a much to the beauty of the earth, and augments th of our innocent pleasures.

With which may be joined another reflection, viz.- considering light as compounded of rays of seven di colours (of which there can be no doubt, because be resolved into these rays by simply passing it th a prism), the constituent parts must be well mix blended together, to produce a fluid so clear and less as a beam of light is, when received from the

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[44] The substitution of the undulatory for the atomic of light would produce no alteration whatever in the a *conclusions*; and, so far from diminishing, would rat

astonishment which the phenomena of Optics are
to excite. The same may be said of the disco-
le partly since Dr. Paley's time, partly imme-
re the composition of his work, of the two other
ys which accompany those of light; the *calorific*,
king, which partly mix with the *colorific*, or
ing, of the spectrum, and partly fall beyond the
gible rays; and the *chemical*, which affect certain
ts, without either producing illumination or ex-
and which are to be found among and beyond
efrangible rays: So that a beam of white light
three kinds of ray, and one of these kinds consists
ibdivisions, at least according to the Newtonian
ich divides the colours into seven instead of innu-
dations of shades.

CHAPTER XXII.

ASTRONOMY.*

My opinion of Astronomy has always been that it is not the best medium through which to prove the agency of an intelligent Creator; but that, this being proved, it shows, beyond all other sciences, the magnificence of his operations. The mind which is once convinced, it raises to sublimer views of the Deity than any other subject affords; but it is not so well adapted as some other subjects are to the purpose of argument. We are destitute of the means of examining the constitution of the heavenly bodies. The very simplicity of their appearance is against them. We see nothing but bright points, luminous circles, or the phases of spheres reflecting the light which falls upon them. Now we deduce design from relation, aptitude, and correspondence of *parts.* Some degree, therefore, of *complexity* is necessary to render a subject fit for this species of argument. But the heavenly bodies do not, except perhaps in the instance of Saturn's ring, present themselves to our observation as compounded of parts at all. This, which may be a perfection in them, is a disadvantage to us, as inquirers after their nature. They do not come within our mechanics.

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* For the articles of this chapter marked with an asterisk, I am indebted to some obliging communications received (through the hands of the Lord Bishop of Elphin) from the Rev. J. Brinkley, M.A., Andrew's Professor of Astronomy in the University of Dublin.—(*Note of the Author.*)—[Professor Brinkley was afterwards, as is well known, Bishop of Cloyne. His lordship, upon being made acquainted with the plan of the present publication, kindly communicated the notes now added, and which are marked with his name.]

And what we say of their forms is true of their *motions*. Their motions are carried on without any sensible intermediate apparatus; whereby we are cut off from one principal ground of argumentation—analogy. We have nothing wherewith to compare them; no invention, no discovery, no operation or resource of art, which, in this respect, resembles them. Even those things which are made to imitate and represent them—such as orreries, planetaria, celestial globes, &c.—bear no affinity to them, in the cause and principle by which their motions are actuated. I can assign for this difference a reason of utility—*viz.*, a reason why, though the action of *terrestrial* bodies upon each other be, in almost all cases, through the intervention of solid or fluid substances, yet central attraction does not operate in this manner. It was necessary that the intervals between the planetary orbs should be devoid of any *inert* matter, either fluid or solid, because such an intervening substance would, by its resistance, destroy those very motions which attraction is employed to preserve. This may be a final cause of the difference; but still the difference destroys the analogy.

Our ignorance, moreover, of the *sensitive* natures by which other planets are inhabited, necessarily keeps from us the knowledge of numberless utilities, relations, and subserviencies, which we perceive upon our own globe.

After all, the real subject of admiration is, that we understand so much of astronomy as we do. That an animal confined to the surface of one of the planets; bearing a less proportion to it than the smallest microscopic insect does to the plant it lives upon; that this little, busy, inquisitive creature, by the use of senses which were given to it for its domestic necessities, and by means of the assistance of those senses which it has had the art to procure, should have been enabled to observe the whole system of worlds to which its own belongs; the *changes of place* of the immense globes which compose it; and with such accuracy as to mark out beforehand the situation in the heavens in which they will be found at any future point of time; and that these bodies, after sailing through regions of void and trackless space, should arrive at the place where they were expected, not within a minute, but within a few seconds of a minute, of the time prefixed and predicted: all this is wonderful, whether we refer our admiration to the constancy of the heavenly motions themselves, or to the perspicacity and precision with which they have been noticed by mankind. Nor is this the whole, nor indeed the chief part, of what astronomy teaches. By bringing reason to bear upon observation (the acutest reasoning upon the exactest observation), the astronomer has been able, out of the "mystic dance," and the confusion (for such it is) under which the motions of the heavenly bodies present themselves to the eye of a mere gazer upon the skies, to elicit their order and their real paths.

Our knowledge, therefore, of astronomy is admirable, though imperfect; and, amidst the confessed desiderata and desideranda, which impede our investigation of the wisdom of the Deity in these the grandest of his works, there are to be found, in the phenomena, ascertained circumstances and laws, sufficient to indicate an intellectual agency in three of its principal operations, viz., in choosing, in determining, in regulating; in *choosing* out of a boundless variety of suppositions which were equally possible, that which is beneficial; in *determining* what, left to itself, had a thousand chances against conveniency, for one in its favour; in *regulating* subjects, as to quantity and degree, which, by their nature were unlimited with respect to either. It will be our business to offer, under each of these heads, a few instances, such as best admit of a popular explication.[a]

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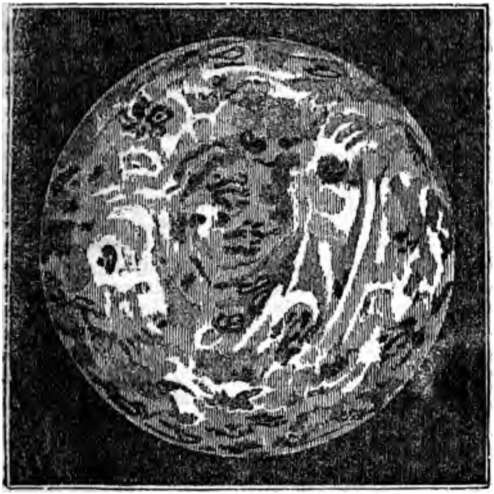
[a] This cut represents a telescopic view of the Sun, showing e of the remarkable spots which have occasionally surface, the largest sometimes exceeding

I. Amongst proofs of choice, one is, fixing the source of light and heat in the *centre* of the system. The sun is ignited and luminous; the planets, which move round him, are cold and dark. There seems to be no antecedent necessity for this order. The sun might have been an opaque mass; some one, or two, or more, or any, or all, the planets, globes of fire. There is nothing in the nature of the heavenly bodies which requires that those which are stationary should be on fire, that those which

size of the whole Earth. Astronomers, by closely observing the motion which these spots have across the Sun's disc, and the perspective changes which they undergo in assuming a

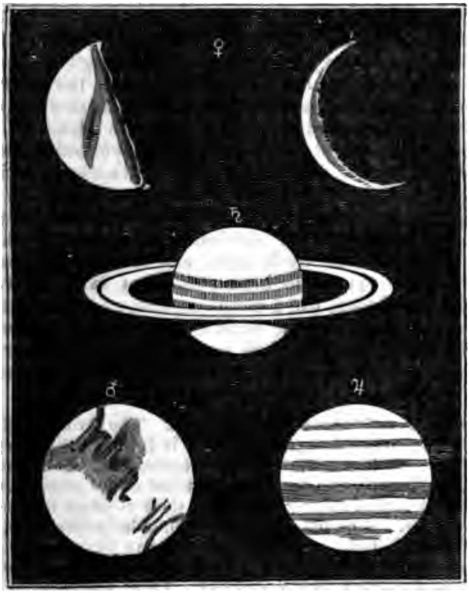


foreshortened, or oval form, as they approach his edge, previous to their disappearance, have greatly assisted the reasoning, which *proves his form to* be spherical, and that he has *a rotation on his axis.*

move should be cold; for, in fact, comets are bodies o fire, or at least capable of the most intense heat, yet revolve round a centre: nor does this order obtain betwee the primary planets and their secondaries, which are a opaque. When we consider, therefore, that the sun i one; that the planets going round it are, at least, seven that it is indifferent to their nature which are luminou and which are opaque: and also in what order, with respect to each other, these two kinds of bodies are di posed; we may judge of the improbability of the present arrangement taking place by chance.

If, by way of accounting for the state in which we fin the solar system, it be alleged (and this is one amongs the guesses of those who reject an intelligent Creator that the planets themselves are only cooled or coo ing masses, and were once, like the sun, many thousan times hotter than red hot iron; then it follows, that th sun also himself must be in his progress towards growin cold; which puts an end to the possibility of his havin existed as he is from eternity. This consequence arise out of the hypothesis with still more certainty, if w make a part of it, what the philosophers who maintain have usually taught, that the planets were originall masses of matter, struck off in a state of fusion, from th body of the sun, by the percussion of a comet, or by shock from some other cause, with which we are n acquainted: for, if these masses, partaking of the natu and substance of the sun's body, have in process of tim lost their heat, that body itself, in time likewise, n matter in how much longer time, must lose its heat als and therefore be incapable of an eternal duration in th state in which we see it, either for the time to come, c the time past.

The preference of the present to any other mode c distributing luminous and opaque bodies, I take to b evident. It requires more astronomy than I am able t lay before the reader to show, in its particulars, wha would be the effect to the system, of a dark body at th centre and one of the planets being luminous: but *think it manifest,* without either plates or calculation first, that supposing the necessary proportion of magnitude between the central and the revolving bodies to be preserved, the ignited planet would not be sufficient to illuminate and warm the rest of the system; secondly, that its light and heat would be imparted to the other planets much more irregularly than light and heat are now received from the sun.[46]



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[46] This cut represents the four great planets, as seen through telescopes of considerable powers. Each planet is marked by the symbol which astronomers have for ages been accustomed to use. ♄ is Saturn with his two rings; which are huge bodies, the *larger having* a diameter more than 25 times *that of our earth, or above* 200,000 miles, and moving with

(*) II. Another thing, in which a choice appears to be exercised, and in which, amongst the possibilities out of which the choice was to be made, the number of those which were wrong bore an infinite proportion to the number of those which were right, is in what geometricians call the *axis of rotation.* This matter I will endeavour to explain. The earth, it is well known, is not an exact globe, but an oblate spheroid, something like an orange. Now the axes of rotation, or the diameters upon which such a body may be made to turn round, are as many as can be drawn through its centre to opposite points upon its whole surface; but of these axes none are *permanent*, except either its shortest diameter, *i. e.* that which passes through the heart of the orange from the place where the stalk is inserted into it, and which is but one; or its longest diameters, at right angles with the former, which must all terminate in the single circumference which goes round the thickest part of the orange. The shortest diameter is that upon which in fact the earth turns, and it is, as the reader sees, what it ought to be, a permanent axis; whereas, had blind chance, had a casual impulse, had a stroke or push at random, set the earth a-spinning, the odds were infinite but that they had sent it round upon a wrong axis. And what would have been the consequence?

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prodigious swiftness round the planet. The seven satellites, or moons, are not represented. ♃ is Jupiter with his spots or belts; his four moons are not represented. Both Saturn and Jupiter are, like our earth, flattened at the poles, instead of being perfect spheres, owing to their rotatory motion on their axes. ♂ is Mars, with his singularly-formed spots, and reddish light at his poles. ♀ is two figures of Venus, as she is seen in different positions; one like a half-moon, and in the other like a crescent. These *appearances* ar called *phases*, from the Greek, and she is the brightest o all the planets. The bulk of Jupiter is 1281 times greate than that of the Earth, of Saturn 995 times; while that o Venus is nine-tenths and that of Mars one-half the Ear bulk. The bulk of the Sun itself is 1,367,000 times t *the Earth.*

The difference between a permanent axis and another axis is this: When a spheroid in a state of rotatory motion gets upon a permanent axis, it keeps there; it remains steady and faithful to its position: its poles preserve their direction with respect to the plane and to the centre of its orbit: but, whilst it turns upon an axis which is *not* permanent (and the number of those we have seen infinitely exceeds the number of the other), it is always liable to shift and vacillate from one axis to another with a corresponding change in the inclination of its poles. Therefore, if a planet once set off revolving upon any other than its shortest, or one of its longest axes, the poles on its surface would keep perpetually changing, and it never would attain a permanent axis of rotation. The effect of this unfixedness and instability would be, that the equatorial parts of the earth might become the polar, or the polar the equatorial; to the utter destruction of plants and animals, which are not capable of interchanging their situations, but are respectively adapted to their own. As to ourselves, instead of rejoicing in our temperate zone, and annually preparing for the moderate vicissitude, or rather the agreeable succession, of seasons, which we experience and expect, we might come to be locked up in the ice and darkness of the arctic circle, with bodies neither inured to its rigours, nor provided with shelter or defence against them. Nor would it be much better, if the trepidation of our pole, taking an opposite course, should place us under the heats of a vertical sun. But if it would fare so ill with the human inhabitant, who can live under greater varieties of latitude than any other animal; still more noxious would this translation of climate have proved to life in the rest of the creation, and, most perhaps of all, in plants. The habitable earth, and its beautiful variety, might have been destroyed by a simple mischance in the axis of rotation.[47]

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[47] (*Note of Bishop* Brinkley.) Either the e
a solid, an oblate spheroid, as it now exists,

(*) III. All this, however, proceeds upon a supposition of the earth having been formed at first an oblate

taken its present form while a soft or fluid mass. In the former case, the argument for design arising from the body revolving on a permanent axis of rotation is of the strongest possible nature. But the present extended knowledge of geology has rendered it highly probable that the earth was originally an ignited mass in a state of fluidity, ignited to the very surface, and by its rotation in that state took its present form as the result of the mutual attraction of its parts and of its rotatory motion. This must be conceded if we do not admit the choice of a permanent axis of rotation. It is, therefore, in the progress through countless ages of the changes on the surface, from the chaotic or primary formation of the geologists to the most interesting state of the surface as it now exists, that we trace the endless arguments for design. However difficult at first sight to be explained, these changes will, when understood, show *one uniform* system, in which all things work together for good.

If we consider the state of the surface before its cooling in a great degree, it must have been wholly unfitted for animal and vegetable life. The admission of this state necessarily lets in the *posterior* and *successive* creation of vegetables and animals. From the vestiges which remain we may conclude, with the highest degree of probability, that for a very long period the surface was only adapted for vegetables and the lowest description of animal life; afterwards for animals of an amphibious nature, and such as could exist only on the marshy shores of lakes, or in places occasionally covered with water. By degrees this state of the surface gave way to others more fitted for a further supply of animals *to be created.* The principal origin of these changes appears to have been provided in the powers attached to the substances, of whatever nature they may be, existing in the interior of the earth; but these powers have been merely mechanical, and could not originate organized vegetables and animals. The class of changes at the surface, constituting the tertiary formations of the geologist, appear to have been that which was followed by the introduction of a great variety of large animals, many of which are now extinct. The surface was still to be further improved by making it fitted for a wide extension of animals and of their food. This has been done spheroid. There is another supposition: and perhaps our limited information will not enable us to decide between them. The second supposition is, that the earth, being a mixed mass somewhat fluid, took, as it must do, its present form, by the joint action of the mutual gravitation of its parts and its rotatory motion. This, as we have said, is a point in the history of the earth, which our observations are not sufficient to determine. For a very small depth below the surface (but extremely small—less, perhaps, than an eight-thousandth part, compared with the depth of the centre), we find vestiges of ancient fluidity. But this fluidity must have gone down many hundred times farther than we can penetrate, to enable the earth to take its present oblate form: and whether any traces of this kind exist to that depth we are ignorant. Calculations were made a few years ago of the mean density of the earth, by comparing the force of its attraction with the force of attraction of a rock of granite, the bulk of which could be ascertained: and the upshot of the calculation was, that the earth upon an average, through its whole sphere, has twice the density of gra-

by the means afforded for the extension and spreading of alluvial matter, so admirably adapted for the growth of plants, and therefore for the existence of animal life. The changes of surface which have been alluded to are all parts of the same design. Between the successive changes great intervals appear to have elapsed. The imagination is able to form no conception of the length of time since the chaotic state began to change. Notwithstanding the time that must have existed between each change, one uniform plan can be discerned. The animals which we must admit to have been *successively* created, show, by their organization, the same creator. Thus, if we admit the fluid and chaotic state of the earth (the alternative if we do not admit an original spheroidal formation), there cannot be a question as to the powerful arguments to be derived from the change on the surface and its series of organized beings. Indeed, if the matter be well considered, it will appear to many that the most conclusive arguments for design and *continued* superintendence may be deduced from the researches of the modern geologists.—*See Second Note to* Chap. XXV. *infra.*

nite, or above five times that of water. Therefore it cannot be a hollow shell, as some have formerly supposed; nor can its internal parts be occupied by central fire or by water. The solid parts must greatly exceed the fluid parts: and the probability is, that it is a solid mass throughout, composed of substances more ponderous the deeper we go. Nevertheless, we may conceive the present face of the earth to have originated from the revolution of a sphere covered by a surface of a compound mixture; the fluid and solid parts separating, as the surface becomes quiescent. Here then comes in the *moderating* hand of the Creator. If the water had exceeded its present proportion, even but by a trifling quantity, compared with the whole globe, all the land would have been covered: had there been much less than there is, there would not have been enough to fertilize the continent. Had the exsiccation been progressive, such as we may suppose to have been produced by an evaporating heat, how came it to stop at the point at which we see it? Why did it not stop sooner? why at all? The mandate of the Deity will account for this; nothing else will.

IV. Of centripetal forces. By virtue of the simplest law that can be imagined, viz., that a body *continues* in the state in which it is, whether of motion or rest; and, if in motion, goes on in the line in which it was proceeding, and with the same velocity, *unless* there be some cause for change: by virtue, I say, of this law, it comes to pass (what may appear to be a strange consequence), that cases arise, in which attraction, incessantly drawing a body towards a centre, never brings, nor ever will bring, the body to that centre, but keep it in eternal circulation round it. If it were possible to fire off a cannon-ball with a velocity of five miles in a second, and the resistance of the air could be taken away, the cannon-ball would for ever wheel round the earth instead of falling down upon it. This is the principle which sustains the heavenly motions. The Deity having appointed this law to matter (than which, as we have said before, no law could be more simple) has turned it to a wonderful account in constructing planetary systems.

The actuating cause in these systems is an attraction which varies reciprocally as the square of the distance; that is, at double the distance, has a quarter of the force; at half the distance, four times the strength; and so on. Now concerning this law of variation, we have three things to observe: first, that attraction, for any thing we know about it, was just as capable of one law of variation as of another; secondly, that, out of an infinite number of possible laws, those which were admissible for the purpose of supporting the heavenly motions lay within certain narrow limits; thirdly, that of the admissible laws, or those which come within the limits prescribed, the law that actually prevails is the most beneficial. So far as these propositions can be made out, we may be said, I think, to prove *choice*, and *regulation:* choice, out of boundless variety; and regulation, of that which, by its own nature, was, in respect of the property regulated, indifferent and indefinite.

I. First, then, attraction, for anything we know about it, was originally indifferent to all laws of variation depending upon change of distance, *i. e.*, just as susceptible of one law as of another. It might have been the same at all distances; it might have increased as the distance increased: or it might have diminished with the increase of the distance, yet in ten thousand different proportions from the present; it might have followed no stated law at all. If attraction be what Cotes, with many other Newtonians, thought it to be, a primordial property of matter, not dependent upon, or traceable to, any other material cause; then, by the very nature and definition of a primordial property, it stood indifferent to all laws. If it be the agency of something immaterial; then also, for anything we know of it, it was indifferent to all laws. If the revolution of bodies round a centre depend upon vortices, neither are these limited to one law more than another.[48]

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[48] The notion of gravitation being a quality inherent in matter, and which could not be separated from its other qualities *has long been* abandoned. To argue that it is

There is, I know, an account given of attracti which should seem, in its very cause, to assign to it law which we find it to observe; and which, therefc makes that law a law not of choice, but of necessi and it is the account which ascribes attraction to *emanation* from the attracting body. It is probable, t the influence of such an emanation will be proportio to the spissitude of the rays of which it is compos which spissitude, supposing the rays to issue in ri lines on all sides from a point, will be reciprocally as square of the distance. The mathematics of this solut we do not call in question: the question with us whether there be any sufficient reason for believing t attraction is produced by an emanation. For my part

necessarily inherent never could be consistent with the n ordinary perception of the meaning affixed to the te necessary and contingent. All that could really be intend therefore, is what we have just now stated in the first s tence of this note. But that, too, appears wholly groundl The only appearance of a reason was derived from the tensity of all streams of matter proceeding from a centr every direction being weakened in proportion to their di sion, and their diffusion being proportioned to the square the distance (by similar triangles and the property of circle, and generally of similar figures). But suppose overlook the purely hypothetical nature of the connex between such emanations and gravitation (sanctioned as theory in a certain degree seems to be by no less an thority than *Laplace, Méc. Cél.* liv. xv. c. 1), and admit hypothesis that matter, according to its present constitu in other respects, must have gravitation in the inve duplicate ratio; though an important position may be t gained or granted in Natural Philosophy, nothing whate is effected in Natural Theology; for the same power wl endowed matter with those qualities from whence this culiar kind of attractive force results, is only proved to h created that attractive force and bestowed it upon ma mediately instead of immediately. This, in short, is another instance of the argument formerly adverted to un the head of "Instinct," Chap. xviii., and which we tl stated to be of general application.

otally at a loss to comprehend how particles stream- *from* a centre should draw a body *towards* it. The lse, if impulse it be, is all the other way. Nor we find less difficulty in conceiving a conflux of cles, incessantly flowing to a centre, and carrying all bodies along with it, that centre also itself g in a state of rapid motion through absolute space; by what source is the stream fed, or what becomes e accumulation? Add to which, that it seems to y a contrariety of properties, to suppose an ætherial to *act*, but not to *resist*; powerful enough to carry bodies with great force towards a centre, yet, in- stently with the nature of inert matter, powerless erfectly yielding with respect to the motions which t from the projectile impulse. By calculations n from ancient notices of eclipses of the moon, we prove that, if such a fluid exist at all, its resistance ad no sensible effect upon the moon's motion for thousand five hundred years. The truth is, that, pt this one circumstance of the variation of the at- ng force at different distances agreeing with the tion of the spissitude, there is no reason whatever pport the hypothesis of an emanation; and, as it s to me, almost insuperable reasons against it.[49]

) II. Our second proposition is, that, whilst the ble laws of variation were infinite, the *admissible* or the laws compatible with the preservation of the m, lie within narrow limits. If the attracting force varied according to any *direct* law of the distance, have been what it would, great destruction and sion would have taken place. The direct simple rtion of the distance would, it is true, have pro- l an ellipse; but the perturbing forces would have with so much advantage, as to be continually ging the dimensions of the ellipse in a manner in-

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See notes 52 and 54, pp. 100, 106, where Bishop Brink- livers an opinion entitled, undoubtedly, to the greatest t, but which seems somewhat more decided than the s *yet warrant, in* favour of the ætherial fluid.

consistent with our terrestrial creation. For inst
if the planet Saturn, so large and so remote, ha
tracted the earth, both in proportion to the quant
matter contained in it, which it does, and also i
proportion to its distance, *i. e.* if it had pulled the h
for being the farther off (instead of the reverse of
would have dragged out of its course the globe
we inhabit, and have perplexed its motions, to a d
incompatible with our security, our enjoyments, an
bably our existence. Of the *inverse* laws, if the c
petal force had changed as the cube of the distan
in any higher proportion, that is (for I speak t
unlearned), if, at double the distance, the attractive
had been diminished to an eighth part, or to les
that, the consequence would have been that the pl
if they once began to approach the sun, would
fallen into his body; if they once, though by ev
little, increased their distance from the centre,
for ever have receded from it. The laws, theref
attraction, by which a system of revolving bodies
be upholden in their motions, lie within narrow
compared with the possible laws. I much unde
the restriction when I say that, in a scale of a mile
are confined to an inch. All direct ratios of the di
are excluded on account of danger from pertu
forces:[50] all reciprocal ratios, except what lie be

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[50] It has been objected to this statement, and th
above, that such a result would not inevitably happe
planets in any number attracting each other with for
creasing in the direct ratio of their distances, as, i
Sir Isaac Newton has shown ('Principia,' lib. i., pro
how they would revolve in equal times and in ell
orbits (see also the 10th and 58th propositions). In
all motion in elliptical orbits is connected with an in
of the force in the direct ratio of the radius vector,
centre of the figure be the centre of forces, of which
Brinkley must have been, of course, aware—(See
But if the statement in the text be taken to inclu
action of other bodies and systems, on the suppositio
the attraction is universal,—which, it must be remem

the cube of the distance, by the demonstrable consequence that every the least change of distance would, under the operation of such laws, have been fatal to the repose and order of the system. We do not know, that is, we seldom reflect, how interested we are in this matter. Small irregularities may be endured; but, changes within these limits being allowed for, the permanency of our ellipse is a question of life and death to our whole sensitive world.

(*) III. That the subsisting law of attraction falls within the limits which utility requires, when these limits bear so small a proportion to the range of possibilities upon which chance might equally have cast it, is not, with any appearance of reason, to be accounted for, by any other cause than a regulation proceeding from a designing mind. But our next proposition carries the matter somewhat farther. We say, in the third place, that, out of the different laws which lie within the limits of admissible laws, the *best* is made choice of; that there are advantages in this particular law which cannot be demonstrated to belong to any other law; and, concerning some of which, it can be demonstrated that they do not belong to any other.

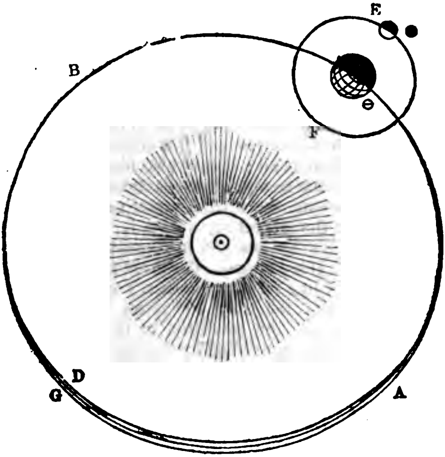
(*) 1. Whilst this law prevails between each particle of matter, the *united* attraction of a sphere, composed of that matter, observes the same law. This property of the law is necessary, to render it applicable to a system composed of spheres, but it is a property which belongs to no other law of attraction that is admissible. The law of variation of the united attraction is in no other case the same as the law of attraction of each particle, one case excepted, and that is of the attraction varying directly as the distance; the inconveniency of which law, in other respects, we have already noticed.

is involved in the very hypothesis of its increasing with the distance,—there seems no solid objection to this part, at least, of the observation; for a rushing together of all the systems, the solar and those of the fixed stars, would be the consequence of the attraction increasing according to any power of *the distance, while those systems* had no motion of projection.

We may follow this regulation somewhat farther, and still more strikingly perceive that it proceeded from a designing mind. A law both admissible and convenient was requisite. In what way is the law of the attracting globes obtained? Astronomical observations and terrestrial experiments show that the attraction of the globes of the system is made up of the attraction of their parts; the attraction of each globe being compounded of the attractions of its parts. Now the admissible and convenient law which exists, could not be obtained in a system of bodies gravitating by the united gravitation of their parts, unless each particle of matter were attracted by a force varying by one particular law, *viz.* varying inversely as the square of the distance: for, if the action of the particles be according to any other law whatever, the admissible and convenient law, which is adopted, could not be obtained. Here then are clearly shown regulation and design. A law both admissible and convenient was to be obtained; the mode chosen for obtaining that law was by making *each* particle of matter act. After this choice was made, then further attention was to be given to each particle of matter, and one and one only particular law of action to be assigned to it. No other law would have answered the purpose intended.

(*) 2. All systems must be liable to *perturbations*. And therefore, to guard against these perturbations, or rather to guard against their running to destructive lengths, is perhaps the strongest evidence of care and foresight that can be given. Now, we are able to demonstrate of our law of attraction, what can be demonstrated of no other, and what qualifies the dangers which arise from cross but unavoidable influences; that the action of the parts of our system upon one another will not cause permanently increasing irregularities, but merely periodical or vibratory ones; that is, they will come to a limit, and then go back again. This we can demonstrate only of a system, in which the following properties conc *viz.* that the force shall be inversely as the square of t distance; the masses of the revolving bodies small, compared with that of the body at the centre; the orbits

uch inclined to one another; and their eccentricity
ttle. In such a system, the grand points are secure.
'he mean distances and periodic times, upon which de-
end our temperature, and the regularity of our year, are
onstant. The eccentricities, it is true, will still vary;
ut so slowly, and to so small an extent, as to produce
inconveniency from fluctuation of temperature and
eason. The same as to the obliquity of the planes of
e orbits. For instance, the inclination of the ecliptic
the equator will never change above two degrees (out
ninety), and that will require many thousand years in
erforming.[51]



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[51] This cut represents the oval A B, nearly circular, in
ich the Earth ⊖ moves round the Sun ⊙ in one of the
—while the Moon, E, moves round the Earth in a similar
ve, E F. These curves vary (as do the paths of all the
nets and their satellites), becoming more and more bulged,
they bulge out by a certain quantity, G D, so as to be
B, and *then the curve they* describe flattens constantly.

It has been rightly also remarked, that, if the great planets, Jupiter and Saturn, had moved in lower spheres;

till it becomes A D B, but never more, in consequence of the four circumstances mentioned in the text.

The celebrated proposition of Laplace, respecting the eccentricities of the planetary orbits, and their deviation from a nearly circular form,—that upon which the stability of the system mainly rests,—may be comprehended by this illustration. Suppose three vessels of different burthen sail from one port to another, and take such courses, that, multiplying the tonnage of each by the square of the deviation in miles which it makes from the straight line, or shortest distance, between the two ports, and adding the three products together, the sum is at every instant of the voyage the same—say 90—the vessels being of 10, 22½, and 90 tons burthen, respectively. It is clear that none of them can ever deviate beyond a certain distance from the straight course, for the greatest possible deviation would be 3 miles —(the square-root of the quotient of 90 divided by the tonnage of the smallest vessel)—and this supposes neither of the other two to deviate at all; if they also had their deviations, that would make the smallest vessel's deviation so much the less. In like manner, the second vessel never could deviate more than 2, nor the largest more than 1. But these deviations would always be lessened in proportion as the other vessels deviated. If we suppose the three to start from three ports in a straight line from each other, and one port to be 64, another 81, and the third 100 miles from the port of destination, and make the condition to be, that the sums of each vessel's tonnage multiplied by the square of its deviation and the products by the sums 8, 9, and 10, respectively (the square-roots of the distances of the three ports of departure) shall be always equal to the same number, *e. g.* 90,—the case will resemble more closely the one we are illustrating; for the proposition of Laplace is, that the sum of the products of e square-roots of the transverse axes of the orbits, multid by the squares of the eccentricities and by the masses, lways the same (*Méc. Cél.* liv. ii. c. 7 and 8; especially 7, 61).

he case which we have taken, however, is only by way 11. nd does not resemble the one in question; Moreover, in order that all the three vessels their influences would have had much more effect as to disturbing the planetary motions, than they now have.

may be able to obey the rule during each part of their course, we must suppose one of them to start from a point on one side of the port, and the same vessel, or another of them, to make a port different from the port of destination. This difficulty would be removed by supposing the condition to be, that the sums of the products should *never exceed* a certain amount.

In the case put it is clear that, practically speaking, no combination among the navigators could make the vessels perform their voyage according to the condition unless by two of the vessels going in the straight line and the third in a line parallel to it. Nothing but a principle acting equally on the crews of all the vessels, like gravitation, or like instinct, could keep them to the terms of the rule if they were all to deviate and to vary in their deviations. But that insects should, by some such instinct, be able to perform an operation of this kind seems quite possible. Each bee acts in the construction of its cell in this way; for it keeps to the rule accurately, and it acts in perfect concert with others; at least it acts so as to produce the effect of concert.

The theorem to which we have here alluded, as well as those two similar theorems which make the mean motions and mean longitudes of the three first satellites of Jupiter follow a certain fixed rule, the difference between thrice the motions and longitudes of the second, and the motions and longitudes of the first added to twice those of the third, being an invariable quantity (that is, 0 in the case of the motions, and 180 degrees in the case of the longitudes), are all deducible by strict mathematical reasoning, but from data which are not necessarily true; for these theorems depend, among other things, upon the motions of revolution throughout the system being in the same direction. Laplace has expressed an opinion, that the relation just mentioned as to Jupiter's satellites was not the same when the motion began, but was established by the mutual actions of these bodies, which he has shown were sufficient to establish the relation at first, as well as to maintain it afterwards. This may or it may not be; that is, it may or it may not be true that those relations were established in the course of the system's action; but no kind of argument arises from hence

While they revolve at so great distances from the they act almost equally on the sun and on the inf planets; which has nearly the same consequence a acting at all upon either.

If it be said, that the planets might have been round the sun in exact circles, in which case, no ch of distance from the centre taking place, the law o riation of the attracting power would have never con question, one law would have served as well as anot an answer to the scheme may be drawn from the sideration of these same perturbing forces. The sy retaining in other respects its present constitu though the planets had been at first sent round in circular orbits, they could not have kept them: a the law of attraction had not been what it is, or at if the prevailing law had transgressed the limits a assigned, every evagation would have been fatal: planet once drawn, as drawn it necessarily must been, out of its course, would have wandered in en error.[52]

against the designing power, even if we admit the suppo of that great mathematician; for then it would only f that the same principle which was appointed to preserv also been appointed to create the relation of stability. *Méc. Cél.* liv. ii. c. 8, s. 66; liv. viii. c. 6, s. 15, and s. 29. See also Mrs. Somerville's truly profound and a able work, *Mechanism of the Heavens*, b. iv. c. 1, s. *et seq.*)

[52] (Note of Bishop Brinkley.) Many suppose attra an emanation, and the law of attraction (the inverse s of the distance) which exists, to be actually *necessar* deducible from *equal* quantities of the attractive force spread over each spherical surface surrounding the attra centre. If this were so, all attracting matter must ac cording to the same law. This is not the case in man stances that might be adduced. The attraction by particles of matter adhere together is obviously not of nature. Chemical action furnishes many exceptions to law. It may, indeed, be said that a polarizing power m *joined to an* attractive force acting as abovementioned.

What we have seen in the law of the centri-
e, *viz.* a choice guided by views of utility, and
: one law out of thousands which might equally
ı place, we see no less in the *figures* of the
›rbits. It was not enough to fix the law of
›etal force, though by the wisest choice; for,
r that law, it was still competent to the planets
›ved in paths possessing so great a degree of
y, as, in the course of every revolution, to be
›ry near to the sun, and carried away to im-
ances from him. The comets actually move
f this sort; and, had the planets done so, in-
›ing round in orbits nearly circular, the change
:xtremity of temperature to another must, in
ast, have destroyed every animal and plant
ırface. Now the distance from the centre at
.anet sets off, and the absolute force of attrac-
t distance, being fixed, the figure of its orbit,
a circle, or nearer to, or farther off from a
a rounder or a longer oval, depends upon two
e velocity with which, and the direction in
: planet is projected. And these, in order to
right result, must be both brought within cer-
w limits. One, and only one, velocity, united
and only one, direction, will produce a perfect
nd the velocity must be near to this velocity,
:ection also near to this direction, to produce

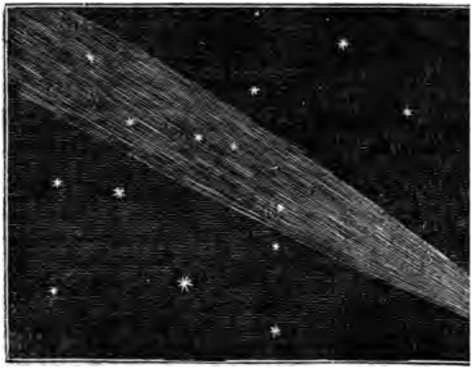
imperfectly, or rather nothing, of the nature of
:ation; but we know it is not extended to the
the sun and planetary masses on each other.
t not extended to these? The simple answer is,
ld not only have been useless, but it would have
vith the purposes for which these bodies were de-
ıus these great bodies are moved by laws of the
›licity, while their component parts act on each
combination of forces of various kinds; which
ır to act at small distances only, while the forces
epend the welfare and preservation of our earth
nets, act through a vast extent of space, and by
and uniform *law,* in which there is no conflicting
of other actions.

orbits, such as the planetary orbits are, nearly circular; that is, ellipses with small eccentricities. The velocity and the direction must *both* be right. If the velocity be wrong, no direction will cure the error; if the direction be in any considerable degree oblique, no velocity will produce the orbit required. Take, for example, the attraction of gravity at the surface of the earth. The force of that attraction being what it is, out of all the degrees of velocity, swift and slow, with which a ball might be shot off, none would answer the purpose of which we are speaking, but what was nearly that of five miles in a second. If it were less than that, the body would not get round at all, but would come to the ground; if it were in any considerable degree more than that, the body would take one of those eccentric courses, those long ellipses, of which we have noticed the inconveniency. If the velocity reached the rate of seven miles in a second, or went beyond that, the ball would fly off from the earth, and never be heard of more. In like manner with respect to the *direction*; out of the innumerable angles in which the ball might be sent off (I mean angles formed with a line drawn in the centre), none would serve but what was nearly a right one: out of the various directions in which the cannon might be pointed, upwards and downwards, every one would fail, but what was exactly or nearly horizontal. The same thing holds true of the planets: of our own amongst the rest. We are entitled therefore to ask, and to urge the question, Why did the projectile velocity and projectile direction of the earth happen to be nearly those which would retain it in a *circular* form? Why not one of the infinite number of velocities, one of the infinite number of directions, which would have made it approach much nearer to, or recede much farther from, the sun?

The planets going round, all in the same direction, and all nearly in the same plane, afforded to Buffon a ground for asserting, that they had all been shiver from the sun by the same stroke of a comet, and by th stroke projected into their present orbits. Now, besi *that this is to* attribute to chance the fortunate conc ity and direction which we have been here hypothesis, as I apprehend, is inconsistent sical laws by which the heavenly motions If the planets were struck off from the sun, they would return to the surface of ı. Nor will this difficulty be got rid of, that the same violent blow which shat-'s surface, and separated large fragments d the sun himself out of his place; for, the f this would be that the sun and system of ments would have a progressive motion, , may possibly be the case with our sys-ı each fragment would, in every revolution, urface of the sun again. The hypothesis icted by the vast difference which subsists *diameters* of the planetary orbits. The aturn from the sun (to say nothing of Sidus) is nearly five-and-twenty times that a disparity which it seems impossible to Buffon's scheme. Bodies starting from e, with whatever difference of direction or set off, could not have been found at these nces from the centre, still retaining their orbits. They must have been carried to istances, before they were projected.*

ppose the matter of the system to be accumu-ntre by its gravity, *no* mechanical principles, ance of this power of gravity, could separate into such parts as the sun and planets; ing them to their different distances, project several directions, preserving still the quality -action, or the state of the centre of gravity Such an exquisite structure of things could the contrivance and powerful influences of ree, and most potent agent. The same powers, ı, at present, govern the material universe, various motions, are *very different* from those essary to have produced it from nothing, or l it in the admirable form in which it now *claurin's Account of Newton's* Philosophy,

To conclude: In astronomy, the great thin
raise the imagination to the subject, and that oft
in opposition to the impression made upon the sens
illusion, for example, must be gotten over arisi
the distance at which we view the heavenly bodi
the apparent *slowness* of their motions.[53] Th



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[53] This cut represents the comet of 1811, the fi
being seen through its tail, which extended 123,00
miles. The period of its revolution is calculated
3,300 years. The great comet of 1680 was calcu
Sir Isaac Newton to have a tail of 80,000,000 o
immediately after its perihelion, a periodic time of 57
and a velocity, when nearest the sun, of 880,000 mi
hour. Its orbit is so much elongated that its grea
tance from the sun is estimated at near 3,000 mi
miles, and its least at only 150,000 miles. Halley'
which appeared in 1682, 1759, and 1835,—probabl
1531 and 1607,—has a mean distance from the sun
millions of miles, the earth's mean distance being 96,
but while the earth's orbit is so nearly circular
planet's greatest distance is only a thirtieth part m
its smallest, this comet's aphelion (or greatest) dis
above 3,355 millions, and its perihelion (or least)

some hours in getting half a yard from a star
ouched. A motion so deliberate we may think
ided. But what is the fact? The moon, in
ll this while, driving through the heavens at
f considerably more than two thousand miles in
which is more than double of that with which
hot off from the mouth of a cannon. Yet is
igious rapidity as much under government, as
net proceeded ever so slowly, or were con-
its course inch by inch. It is also difficult to
imagination to conceive (what yet, to judge
of the matter, it is necessary to conceive) how
re may so express it, the heavenly bodies are.
globes, held by nothing, confined by nothing,
d into free and boundless space, each to seek
by the virtue of an invisible principle; but a
, one, common, and the same in all, and ascer-
To preserve such bodies from being lost, from
together in heaps, from hindering and distract-
nother's motions, in a degree inconsistent with
nuing order; *h. e.* to cause them to form planet-
ns, systems that, when formed, can be upheld,
; especially, systems accommodated to the organ-
sensitive natures, which the planets sustain, as
to be the case, where alone we can know what
is, upon our earth: all this requires an intelli-
rposition, because it can be demonstrated con-
it, that it requires an adjustment of force,

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illions, or sixty-one times less. So the transverse
) axis of its orbit is four times the length of the
(or shorter) axis; whereas the two axes of the
bit differ by only a 7000th part from one another.
e planetary orbits are nearly circular also, that of
ing the most elongated, and in the proportion of
3. But the orbits of the comets have every variety
s well as size, and their motion the greatest differ-
elocity; yet they appear all to follow the same
ws, and these the same by which the planetary
re governed.

distance, direction, and velocity, out of the rea chance to have produced; an adjustment, in its vi utility, similar to that which we see in ten tho subjects of nature which are nearer to us, but in p and in the extent of space through which that pow exerted, stupendous.[54]

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[54] (Note of Bishop Brinkley. See Note 49.) Sinc publication of Dr. Paley's 'Natural Theology' it has ascertained that a resisting medium is actually di through our system. But it is of so rare a nature, th planets will not be affected by it for an immense p The existence of this resisting medium has been ascert by the successive revolutions of the small comet, the or which was first accurately computed by M. Encke, a identity verified on several successive returns. We before a knowledge of the weak action of comets o planets, and of the consequent smallness of their masse was also inferred that they were bodies of small densit consequently would be more sensibly affected in their m through a resisting medium. This comet was found in by Miss Herschel, and observed also by her brother. account of it, when considered with reference to wha since been ascertained as to the resistance it meets wi its course, is remarkable (vide Phil. Trans. 1796, p. 13 "The comet is now centrically on a small star. It is a telescopic star of about the eleventh or twelfth magni and is double, very unequal: with a power of 287 I ca the smallest of the two stars perfectly well. This s how little density there is in the comet, which is evid nothing but what may be called a collection of vapo This comet is also remarkable for the shortness of its pe about three and a half years, not receding so far from sun as the planet Jupiter. In the solar system the differ between the two classes of bodies which revolve round sun, and are retained in their orbits by the solar actio most marked and distinct. Comets so numerous serve purposes entirely unknown to us. Indeed, hitherto no bable conjecture has been formed as to those purposes. T they are not the habitations of beings similar to those wh exist on the earth is nearly certain. The earth and pl appear wisely adapted, in a variety of ways, for the c

But many of the heavenly bodies, as the sun and fixed s, are *stationary*. Their rest must be the effect of bsence or of an equilibrium of attractions. It proves , that a projectile impulse was originally given to e of the heavenly bodies, and not to others. But her: if attraction act at all distances, there can only ne quiescent centre of gravity in the universe; and bodies whatever must be approaching this centre or lving round it. According to the first of these sup-

and preservation of animals and vegetables. The ets are not so adapted. In one case orbits nearly circular e required, in the other they were not required.

here is another circumstance in which design appears ngly marked, although we cannot explain the purport of The planets appear to be placed at distances from the according to a certain law. This was remarked by essor Bode, and that the law was not complete unless a et existed between Mars and Jupiter. The new planets afterwards discovered, each of them circulating between ter and Mars, at a distance from the sun conformable to onjectured law.* The cause of more than one planet found at this distance has, with some degree of proba- been derived from the hypothesis that a large planet een shattered into fragments, which fragments are the ts Ceres, Vesta, Pallas, and Juno. That wonderful es occasionally offer themselves to our notice, as won- as the destruction of a planet, is exemplified in the rance and disappearance of a fixed star. A star sud- appeared in 1571, of a degree of splendour exceeding other fixed stars. It was seen during sixteen months, ntinually diminished in brightness till it disappeared. e circumstances of it are well attested by many astro- s, and others. It remained fixed in one spot of the s without changing its place among the other stars by erceptible quantity. Although astronomical instru- at that time did not admit of a degree of precision to pared with those of the present time, yet the observa- ade on it by several astronomers fully suffice to show distance from us must have been at least between d 4000 times that of the sun from the earth, or millions of miles.

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* *See first note to chap.* xxv. *infra.*

positions, if the duration of the world had been long enough to allow of it, all its parts, all the great bodies of which it is composed, must have been gathered together in a heap round this point. No changes however which have been observed, afford us the smallest reason for believing that either the one supposition or the other is true: and then it will follow, that attraction itself is controlled or suspended by a superior agent; that there is a power above the highest of the powers of material nature; a will which restrains and circumscribes the operations of the most extensive.*

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* It must here, however, be stated that many astronomers deny that any of the heavenly bodies are absolutely stationary. Some of the brightest of the fixed stars have certainly small motions; and of the rest the distance is too great, and the intervals of our observation too short, to enable us to pronounce with certainty that they may not have the same. The motions in the fixed stars which have been observed are considered either as proper to each of them, or as compounded of the motion of our system, and of motions proper to each star. By a comparison of these motions, a motion in our system is supposed to be discovered. By continuing this analogy to other and to all systems, it is possible to suppose that attraction is unlimited, and that the whole material universe is revolving round some fixed point within its containing sphere or space.—*Note of the Author.*

CHAPTER XXIII.

OF THE PERSONALITY OF THE DEITY.

TRIVANCE, if established, appears to me to prove
·y thing which we wish to prove. Amongst other
igs, it proves the *personality* of the Deity, as distin-
ihed from what is sometimes called nature, sometimes
ed a principle: which terms, in the mouths of those
› use them philosophically, seem to be intended to
iit and to express an efficacy, but to exclude and to
y a personal agent. Now that which can contrive,
ch can design, must be a person. These capacities
stitute personality, for they imply consciousness and
ıght. They require that which can perceive an end
purpose; as well as the power of providing means,
directing them to their end.* They require a centre
which perceptions unite, and from which volitions
r; which is mind. The acts of a mind prove the
stence of a mind; and in whatever a mind resides, is
erson. The seat of intellect is a person. We have
uthority to limit the properties of mind to any par-
lar corporeal form, or to any particular circumscrip-
of space. These properties subsist, in created
ıre, under a great variety of sensible forms. Also
ry animated being has its *sensorium;* that is, a cer-
portion of space, within which perception and
tion are exerted. This sphere may be enlarged to
indefinite extent; may comprehend the universe;
, being so imagined, may serve to furnish us with as
d a notion as we are capable of forming, of the *im-*
sity of the Divine Nature, *i. e.* of a Divine Being,

Priestley's *Letters to a Philosophical Unbeliever*, p.
ed. 2.

infinite, as well in essence as in power; yet nevertheless a person.

"No man hath seen God at any time." And this, I believe, makes the great difficulty. Now it is a difficulty which chiefly arises from our not duly estimating the state of our faculties. The Deity, it is true, is the object of none of our senses; but reflect what limited capacities animal senses are. Many animals seem to have but one sense, or perhaps two at the most; touch and taste. Ought such an animal to conclude against the existence of odours, sounds, and colours? To another species is given the sense of smelling. This is an advance in the knowledge of the powers and properties of nature: but, if this favoured animal should infer from its superiority over the class last described, that it perceived everything which was perceptible in nature, it is known to us, though perhaps not suspected by the animal itself, that it proceeded upon a false and presumptuous estimate of its faculties. To another is added the sense of hearing; which lets in a class of sensations entirely unconceived by the animal before spoken of; not only distinct, but remote from any which *it* had ever experienced, and greatly superior to them. Yet this last animal has no more ground for believing that its senses comprehend all things, and all properties of things, which exist, than might have been claimed by the tribes of animals beneath it; for we know that it is still possible to possess another sense, that of sight, which shall disclose to the percipient a new world. This fifth sense makes the animal what the human animal is: but to infer that possibility stops here; that either this fifth sense is the last sense, or that the five comprehend all existence,—is just as unwarrantable a conclusion as that which might have been made by any of the different species which possessed fewer, or even by that, if such there be, which possessed only one. The conclusion of the one-sense animal, and the conclusion of the five-sense animal, stand upon the same authority. There may be more and other senses than *those which we have.* There may be senses suited to the perception of the powers, properties, and substanc of spirits. These may belong to higher orders of r tional agents; for there is not the smallest reason f supposing that we are the highest, or that the scale creation stops with us.

The great *energies* of nature are known to us only b their effects. The substances which produce them ar as much concealed from our senses as the Divine essenc itself. *Gravitation*, though constantly present, thoug constantly exerting its influence, though everywher around us, near us, and within us; though diffuse throughout all space, and penetrating the texture of a bodies with which we are acquainted, depends, if upo a fluid, upon a fluid which, though both powerful an universal in its operation, is no object of sense to us; i upon any other kind of substance or action, upon a substance and action from which *we* receive no distinguishable impressions. Is it then to be wondered at that i should, in some measure, be the same with the Divin nature?

Of this, however, we are certain, that whatever th Deity be, neither the *universe*, nor any part of it whic we see, can be He. The universe itself is merely collective name: its parts are all which are real; o which are *things*. Now inert matter is out of the question; and organized substances include marks of contrivance. But whatever includes marks of contrivance, whatever, in its constitution, testifies design, necessarily carries us to something beyond itself, to some other being, to a designer prior to, and out of itself. No animal, for instance, can have contrived its own limbs and senses: can have been the author to itself of the design with which they were constructed. That supposition involves all the absurdity of self-creation, *i. e.* of acting without existing. Nothing can be God, which is ordered by a wisdom and a will, which itself is void of; which is indebted for any of its properties to contrivance *ab extra*. The *not* having that in his nature which requi exertion of another prior being (which proper *times called self-sufficiency*, and sometimes hension) appertains to the Deity, as his essential distinction, and removes his nature from that of all things which we see. Which consideration contains the answer to a question that has sometimes been asked, namely, Why, since something or other must have existed from eternity, may not the present universe be that something? The contrivance perceived in it proves that to be impossible. Nothing contrived can, in a strict and proper sense, be eternal, forasmuch as the contriver must have existed before the contrivance.

Wherever we see marks of contrivance, we are led for its cause to an *intelligent* author. And this transition of the understanding is founded upon uniform experience. We see intelligence constantly contriving; that is, we see intelligence constantly producing effects, marked and distinguished by certain properties; not certain particular properties, but by a kind and class of properties, such as relation to an end, relation of parts to one another, and to a common purpose. We see, wherever we are witnesses to the actual formation of things, nothing except intelligence producing effects so marked and distinguished. Furnished with this experience, we view the productions of nature. We observe *them* also marked and distinguished in the same manner. We wish to account for their origin. Our experience suggests a cause perfectly adequate to this account. No experience, no single instance or example, can be offered in favour of any other. In this cause, therefore, we ought to rest; in this cause the common sense of mankind has, in fact, rested, because it agrees with that, which, in all cases, is the foundation of knowledge,—the undeviating course of their experience. The reasoning is the same as that by which we conclude any ancient appearances to have been the effects of volcanoes or inundations; namely, because they resemble the effects which fire and water produce before our eyes; and because we have never known these effects to result from any other operation. And this resemblance may subsist in so many circumstances, as not to leave us under the smallest doubt in *forming* our opinion. Men are not deceived by this

asoning: for whenever it happens, as it sometimes
es happen, that the truth comes to be known by direct
formation, it turns out to be what was expected. In
ke manner, and upon the same foundation (which in
uth is that of experience), we conclude that the works
nature proceed from intelligence and design; because,
the properties of relation to a purpose, subserviency
a use, they resemble what intelligence and design are
nstantly producing, and what nothing except intelli-
nce and design ever produce at all. Of every argu-
ent, which would raise a question as to the safety of
is reasoning, it may be observed, that if such argument
listened to, it leads to the inference, not only that
e present order of nature is insufficient to prove the
istence of an intelligent Creator, but that no imagin-
le order would be sufficient to prove it, that *no* con-
ivance, were it ever so mechanical, ever so precise,
er so clear, ever so perfectly like those which we our-
lves employ, would support this conclusion—a doctrine
which I conceive no sound mind can assent.

The force, however, of the reasoning is sometimes
k by our taking up with mere names. We have
ady noticed,* and we must here notice again, the
application of the term "law," and the mistake con-
ing the idea which that term expresses in physics,
never such idea is made to take the place of power,
still more of an intelligent power, and as such, to
signed for the cause of any thing, or of any property
y thing, that exists. This is what we are secretly
do, when we speak of organized bodies (plants
stance, or animals) owing their production, their
their growth, their qualities, their beauty, their
o any law or laws of nature; and when we are
ted to sit down with that answer to our inquiries
ning them. I say once more, that it is a perver-
language to assign any law, as the efficient, ope-
ause of any thing. A law pre-supposes an agent,
only the mode according to which an agent pro-

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* *Chap. i. sect. vii.*

ceeds; it implies a power, for it is the order according to which that power acts. Without this agent, without this power, which are both distinct from itself, the "law" does nothing; is nothing.

What has been said concerning "law," holds true of *mechanism.* Mechanism is not itself power. Mechanism, without power, can do nothing. Let a watch be contrived and constructed ever so ingeniously; be its parts ever so many, ever so complicated, ever so finely wrought or artificially put together, it cannot *go* without a weight or spring, *i. e.* without a force independent of, and ulterior to, its mechanism. The spring acting at the centre, will produce different motions and different results, according to the variety of the intermediate mechanism. One and the self-same spring, acting in one and the same manner, *viz.* by simply expanding itself, may be the cause of a hundred different and all useful movements, if a hundred different and well-devised sets of wheels be placed between it and the final effect: *e. g.* may point out the hour of the day, the day of the month, the age of the moon, the position of the planets, the cycle of the years, and many other serviceable notices; and these movements may fulfil their purposes with more or less perfection, according as the mechanism is better or worse contrived, or better or worse executed, or in a better or worse state of repair: *but in all cases it is necessary that the spring act at the centre.* The course of our reasoning upon such a subject would be this: By inspecting the watch, even when standing still, we get a proof of contrivance, and of a contriving mind, having been employed about it. In the form and obvious relation of its parts, we see enough to convince us of this. If we pull the works in pieces, for the purpose of a closer examination, we are still more fully convinced. But, when we see the watch *going*, we see proof of another point, *viz.* that there is a power somewhere, and somehow or other applied to it; a power in action;—that there is more in the subject than the mere wheels of the machine;—that there is a *secret* spring, or a gravitating plummet;—in a word, that there is force, and energy, as well as mechanism.

So, then, the watch in motion establishes to the observer two conclusions: One,—that thought, contrivance, and design, have been employed in the forming, proportioning, and arranging of its parts, and that whoever or wherever he be, or were, such a contriver there is, or was: The other,—that force or power, distinct from mechanism, is, at this present time, acting upon it. If I saw a hand-mill even at rest, I should see contrivance: but if I saw it grinding, I should be assured that a hand was at the windlass, though in another room. It is the same in nature. In the works of nature we trace mechanism; and this alone proves contrivance: but living, active, moving, productive nature, proves also the exertion of a power at the centre: for, wherever the power resides may be denominated the centre.

The intervention and disposition of what are called "*second causes*" fall under the same observation. This disposition is or is not mechanism, according as we can or cannot trace it by our senses and means of examination. That is all the difference there is; and it is a difference which respects our faculties, not the things themselves. Now where the order of second causes is mechanical, what is here said of mechanism strictly applies to it. But it would be always mechanism (natural chemistry, for instance, would be mechanism), if our senses were acute enough to descry it. Neither mechanism, therefore, in the works of nature, nor the intervention of what are called second causes (for I think that they are the same thing), excuses the necessity of an agent distinct from both.

If, in tracing these causes, it be said that we find certain general properties of matter which have nothing in them that bespeaks intelligence, I answer, that still the *managing* of these properties, the pointing and directing them to the uses which we see made of them, demands intelligence in the highest degree. For example: suppose animal secretions to be elective attractions, and that *such and such attractions* universally belong to such and such substances—in all which there is no intellect concerned; still the choice and collocation of these substances, the fixing upon right substances, and disposing them in right places, must be an act of intelligence. What mischief would follow were there a single transposition of the secretory organs; a single mistake in arranging the glands which compose them!

There may be many second causes, and many courses of second causes, one behind another, between what we observe of nature, and the Deity: but there must be intelligence somewhere: there must be more in nature than what we see; and, amongst the things unseen, there must be an intelligent, designing author. The philosopher beholds with astonishment the production of things around him. Unconscious particles of matter take their stations, and severally range themselves in an order, so as to become collectively plants or animals, *i. e.* organised bodies, with parts bearing strict and evident relation to one another, and to the utility of the whole: and it should seem that these particles could not move in any other way than as they do; for they testify not the smallest sign of choice, or liberty, or discretion. There may be particular intelligent beings, guiding these motions in each case: or they may be the result of trains of mechanical dispositions, fixed beforehand by an intelligent appointment, and kept in action by a power at the centre. But, in either case, there must be intelligence.

The minds of most men are fond of what they call a *principle*, and of the appearance of simplicity, in accounting for phænomena. Yet this principle, this simplicity, resides merely in the *name:* which name, after all, comprises, perhaps, under it a diversified, multifarious, or progressive operation, distinguishable into parts. The power in organised bodies, of producing bodies like themselves, is one of these principles. Give a philosopher this, and he can get on. But he does not reflect what this mode of production, this principle (if such he choose to call it) requires; how much it presupposes; what an apparatus of instruments, some of *which are strictly* mechanical, is necessary to its success;

at a train it includes of operations and changes, one
ceeding another, one related to another, one minister-
to another, all advancing, by intermediate, and, fre-
ntly, by sensible steps, to their ultimate result! Yet,
ause the whole of this complicated action is wrapped
in a single term, *generation*, we are to set it down as
elementary principle; and to suppose, that when we
e resolved the things which we see into this prin-
le, we have sufficiently accounted for their origin,
hout the necessity of a designing, intelligent Creator.
e truth is, generation is not a principle, but a *process*.
e might as well call the casting of metals a principle;
might, so far as appears to me, as well call spinning
l weaving principles: and then, referring the texture
loths, the fabric of muslins and calicoes, the patterns
diapers and damasks, to these, as principles, pretend
lispense with intention, thought, and contrivance, on
part of the artist; or to dispense, indeed, with the
essity of any artist at all, either in the manufacturing
the article, or in the fabrication of the machinery
which the manufacture was carried on.

nd, after all, how, or in what sense is it true, that
als produce their *like?* A butterfly, with a pro-
s instead of a mouth, with four wings and six legs,
ces a hairy caterpillar, with jaws and teeth, and
en feet. A frog produces a tadpole. A black
, with gauze wings, and a crusty covering, produces
e, smooth, soft worm; an ephemeron fly, a cod-
aggot. These, by a progress through different
f life, and action, and enjoyment (and, in each
ovided with implements and organs appropriated
mporary nature which they bear), arrive at last
rm and fashion of the parent animal. But all
rocess, not principle; and proves, moreover,
roperty of animated bodies, of producing their
ngs to them, not as a primordial property, not
nd necessity in the nature of things, but as
f œconomy, wisdom, and design; because the
elf assumes diversities, and submits to devi-

ations dictated by intelligible utilities, and serving distinct purposes of animal happiness.

The opinion, which would consider "generation" as a *principle* in nature; and which would assign this principle as the cause, or endeavour to satisfy our minds with such a cause, of the existence of organised bodies, is confuted, in my judgment, not only by every mark of contrivance discoverable in those bodies, for which it gives us no contriver, offers no account whatever; but also by the further consideration, that things generated possess a clear relation to things *not* generated. If it were merely one part of a generated body bearing a relation to another part of the same body; as the mouth of an animal to the throat, the throat to the stomach, the stomach to the intestines, those to the recruiting of the blood, and, by means of the blood, to the nourishment of the whole frame: or if it were only one generated body bearing a relation to another generated body; as the sexes of the same species to each other, animals of prey to their prey, herbivorous and granivorous animals to the plants or seeds upon which they feed; it might be contended, that the whole of this correspondency was attributable to generation, the common origin from which these substances proceeded. But what shall we say to agreements which exist between things generated and things *not generated?* Can it be doubted, was it ever doubted, but that the *lungs* of animals bear a relation to the *air*, as a permanently elastic fluid? They act in it, and by it; they cannot act without it. Now, if generation produced the animal, it did not produce the air: yet their properties correspond. The *eye* is made for *light*, and light for the eye. The eye would be of no use without light, and light perhaps of little without eyes; yet one is produced by generation, the other not. The *ear* depends upon *undulations* of air. Here are two sets of motions; first, of the pulses of the air; secondly, of the drum, bones, and nerves of the ear; sets of motions bearing an evident reference to each other: *yet the one*, and the apparatus for the one, produced by

tervention of generation; the other altogether in-
dent of it.
it be said, that the air, the light, the elements, the
itself, is *generated*; I answer, that I do not com-
nd the proposition. If the term mean any thing
r to what it means when applied to plants or ani-
the proposition is certainly without proof: and, I
draws as near to absurdity as any proposition can
hich does not include a contradiction in its terms.
at a loss to conceive how the formation of the
can be compared to the generation of an animal.
term generation signify something quite different
vhat it signifies on ordinary occasions, it may, by
me latitude, signify any thing. In which case, a
or phrase taken from the language of Otaheite
convey as much theory concerning the origin of
iverse, as it does to talk of its being generated.
know a cause (intelligence) adequate to the ap-
ices which we wish to account for: we have this
continually producing similar appearances: yet re-
this cause, the sufficiency of which we know,
e action of which is constantly before our eyes,
invited to resort to suppositions destitute of a
fact for their support, and confirmed by no ana-
ith which we are acquainted. Were it necessary
uire into the *motives* of men's opinions, I mean
notives separate from their arguments; I should
suspect, that, because the proof of a Deity drawn
he constitution of nature is not only popular but
(which may arise from the cogency of the proof,
indeed its highest recommendation), and because
species almost of *puerility* to take up with it; for
reasons, minds, which are habitually in search of
ion and originality, feel a resistless inclination
ce off into other solutions and other expositions.
uth is, that many minds are not so indisposed to
ing which can be offered to them, as they are to
tness of being content with common reasons: and,
s most to be *lamented*, minds conscious of superi-
re the most liable to this repugnancy.

The "suppositions" here alluded to all agree in character: they all endeavour to dispense with the cessity in nature of a particular, personal intelligen that is to say, with the exertion of an intending, c triving mind, in the structure and formation of the ganised constitutions which the world contains. T would resolve all productions into *unconscious* energ of a like kind, in that respect, with attraction, mag ism, electricity, &c.; without any thing further.

In this, the old system of atheism and the new ag And I much doubt whether the new schemes have vanced any thing upon the old, or done more t changed the terms of the nomenclature. For insta I could never see the difference between the antiqu system of atoms, and Buffon's organic molecules. T philosopher, having made a planet by knocking off fi the sun a piece of melted glass, in consequence of stroke of a comet; and having set it in motion, by same stroke, both round its own axis and the sun; fi his next difficulty to be, how to bring plants and ani upon it. In order to solve this difficulty, we are to pose the universe replenished with particles, endo with life, but without organisation or senses of t own; and endowed also with a tendency to mar themselves into organised forms. The concours these particles, by virtue of this tendency, but wit intelligence, will, or direction (for I do not find any of these qualities are ascribed to them), has prod the living forms which we now see.

Very few of the conjectures, which philosop hazard upon these subjects, have more of pretensio them, than the challenging you to show the direct possibility of the hypothesis. In the present exam there seemed to be a positive objection to the w scheme upon the very face of it; which was that, if case were as here represented, *new* combinations o to be perpetually taking place; new plants and anim or organised bodies which were neither, ought to starting up before our eyes every day. For this, h *ever, our philo*sopher has an answer. Whilst so w

f plants and animals are already in existence,
nsequently, so many " internal moulds," as he
em, are prepared and at hand, the organic par-
un into these moulds, and are employed in sup-
an accession of substance to them, as well for
rowth, as for their propagation. By which
things keep their ancient course. But, says the
ilosopher, should any general loss or destruction
present constitution of organised bodies take
the particles, for want of " moulds" into which
ight enter, would run into different combinations,
plenish the waste with new species of organised
ces.

ere any history to countenance this notion? Is
n that any destruction has been so repaired? any
hus re-peopled?

r as I remember, the only natural appearance
ed by our author, by way of fact whereon to
is hypothesis, is the formation of *worms* in the
es of animals, which is here ascribed to the coa-
f superabundant organic particles, floating about
first passages; and which have combined them-
nto these simple animal forms, for want of inter-
ulds, or of vacancies in those moulds, into which
ight be received. The thing referred to is rather
s of facts, than a single fact; as some other cases
ith equal reason, be included under it. But to
t a fact at all, or, in any sort, applicable to the
n, we must begin with asserting an *equivocal* gene-
contrary to analogy, and without necessity: con-
an analogy, which accompanies us to the very
f our knowledge or inquiries; for wherever, either
s or animals, we are able to examine the subject,
procreation from a parent form: without neces-
r I apprehend that it is seldom difficult to suggest
s by which the eggs, or spawn, or yet invisible
its of these vermin, may have obtained a passage
cavities in which they are found.* Add to this,

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ust I may be excused for not citing, as another fact
to confirm the hypothesis, a grave assertion of this

that their *constancy to their species*, which, I believe, is as regular in these as in the other vermes, decides the question against our philosopher, if, in truth, any question remained upon the subject.

Lastly; these wonder-working instruments, these "internal moulds," what are they after all? what, when examined, but a name without signification; unintelligible, if not self-contradictory; at the best, differing in nothing from the "essential forms" of the Greek philosophy? One short sentence of Buffon's work exhibits his scheme as follows: "When this nutritious and prolific matter, which is diffused throughout all nature, passes through the *internal mould* of an animal or vegetable, and finds a proper matrix, or receptacle, it gives rise to an animal or vegetable of the same species." Does any reader annex a meaning to the expression "internal mould," in this sentence? Ought it then to be said, that, though we have little notion of an internal mould, we have not much more of a designing mind? The very contrary of this assertion is the truth. When we speak of an artificer or an architect, we talk of what is comprehensible to our understanding, and familiar to our experience. We use no other terms, than what refer us for their meaning to our consciousness and observation; what express the constant objects of both: whereas names like that we have mentioned refer us to nothing; excite no idea; convey a sound to the ear, but I think do no more.

Another system, which has lately been brought forward, and with much ingenuity, is that of *appetencies*. The principle, and the short account of the theory, is this: Pieces of soft, ductile matter, being endued with propensities or appetencies for particular actions, would, by continual endeavours, carried on through a long series of generations, work themselves gradually into suitable forms; and, at length, acquire, though perhaps by obscure and almost imperceptible improvements, an organization fitted to the action which their respective propensities

writer, that the branches of trees upon which the stag feeds break out again in his horns. Such *facts* merit no discussion.—(*Note of the Author.*)

had them to exert. A piece of animated matter, for ex
ample, that was endued with a propensity to *fly*, thougl
ever so shapeless, though no other we will suppose tha
a round ball to begin with, would, in a course of ages, i
not in a million of years, perhaps in a hundred million
of years (for our theorists, having eternity to dispose of
are never sparing in time), acquire *wings*. The sam
tendency to locomotion in an aquatic animal, or rathe
in an animated lump, which might happen to be surrounded by water, would end in the production of *fins*
in a living substance, confined to the solid earth, woul
put out *legs* and *feet*; or, if it took a different turn, woul
eak the body into ringlets, and conclude by *crawlin*
on the ground.

Although I have introduced the mention of this the
into this place, I am unwilling to give to it the name
n atheistic scheme, for two reasons: first, because
ir as I am able to understand it, the original propen-
s and the numberless varieties of them (so different
his respect, from the laws of mechanical nature
h are few and simple) are, in the plan itself, at-
ted to the ordination and appointment of an intelli-
and designing Creator: secondly, because, likewise
large postulatum, which is all along assumed and
ipposed, the faculty in living bodies of producing
r bodies organised like themselves, seems to be re-
d to the same cause; at least is not attempted to be
unted for by any other. In one important respect
ever, the theory before us coincides with atheistic
ems, *viz*. in that, in the formation of plants and ani-
in the structure and use of their parts, it does away
causes.[55] Instead of the parts of a plant or animal,

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[55] In one sense this doctrine (if it deserve the name) of
etencies can hardly be said to supersede final causes. For
pose the *conatus* or appetency to have formed an eye, such
we now have it, and constructed as we know it to be, all
uses continue; it is calculated to perform the office re-
ired,—to supply that, the desire of supplying which is
pposed to have produced it. Stating that des
e *production*, appears only to be a covert an
surd *mode of stating* the doctrine of final cau

or the particular structure of the parts, having been intended for the action or the use to which we see them applied; according to this theory, they have themselves grown out of that action, sprung from that use. The theory therefore dispenses with that which we insist upon, the necessity, in each particular case, of an intelligent, designing mind, for the contriving and determining of the forms which organised bodies bear. Give our philosopher these appetencies; give him a portion of living irritable matter (a nerve, or the clipping of a nerve), to work upon: give also to his incipient or progressive forms the power, in every stage of their alteration, of propagating their like; and, if he is to be believed, he could replenish the world with all the vegetable and animal productions which we at present see in it.

The scheme under consideration is open to the same objection with other conjectures of a similar tendency, *viz.* a total defect of evidence. No changes, like those which the theory requires, have ever been observed. All the changes in Ovid's Metamorphoses might have been effected by these appetencies, if the theory were true; yet not an example, nor the pretence of an example, is offered of a single change being known to have taken place. Nor is the order of generation obedient to the principle upon which this theory is built. The mammæ* of the male have not vanished by inusitation;

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* I confess myself totally at a loss to guess at the reason, either final or efficient, for this part of the animal frame; unless there be some foundation for an opinion, of which I draw the hint from a paper of Mr. Everard Home (Phil. Transact. 1799, Pt. 2), viz. that the mammæ of the fœtus may be formed before the sex is determined.[56]—(*Note of the Author.*)

[56] The paper alluded to is upon Hermaphrodites, in vol. lxxxix. p. 157, and the suggestion is in the remarks upon the want of ovaria in certain monstrous births, and the male parts being found instead. The author (Sir E. Home) suggests that this may be explained by supposing the ovum *before* impregnation, to have been equally adapted to *becoming* either a male or a female fœtus.

nec curtorum, per multa sæcula, Judæorum propagini deest præputium. It is easy to say, and it has been said, that the alterative process is too slow to be perceived; that it has been carried on through tracts of immeasurable time; and that the present order of things is the result of a graduation, of which no human records can trace the steps. It is easy to say this; and yet it is still true, that the hypothesis remains destitute of evidence.

The *analogies* which have been alleged are of the following kind: The *bunch* of a camel is said to be no other than the effect of carrying burdens; a service in which the species has been employed from the most ancient times of the world. The first race, by the daily loading of the back, would probably find a small grumous tumour to be formed in the flesh of that part. The next progeny would bring this tumour into the world with them. The life to which they were destined would increase it. The cause which first generated the tubercle being continued, it would go on, through every succession, to augment its size, till it attained the form and the bulk under which it now appears. This may serve for one instance: another, and that also of the passive sort, is taken from certain species of birds. Birds of the *crane* kind, as the crane itself, the heron, bittern, stork, have, in general, their thighs bare of feathers. This privation is accounted for from the habit of wading in water, and from the effect of that element to check the growth of feathers upon these parts; in consequence of which, the health and vegetation of the feathers declined through each generation of the animal; the tender down, exposed to cold and wetness, became weak, and thin, and rare, till the deterioration ended in the result which we see, of absolute nakedness. I will mention a third instance, because it is drawn from an active habit, as the two last were from passive habits; and that is the *pouch* of the pelican. The description which naturalists give of this organ is as follows: "From the lower edges of the under chap hangs a bag, reaching from the whole length of the bill *to the neck*, which is said to be *capable of containing fifteen* quarts of water. This bag

the bird has a power of wrinkling up into the holl
the under chap. When the bag is empty, it is not
but when the bird has fished with success, it is incr
to what an extent it is often dilated. The first
the pelican does in fishing is to fill the bag; and t
returns to digest its burden at leisure. The bird
upon the large fishes, and hides them by dozens
pouch. When the bill is opened to its widest ext
person may run his head into the bird's mouth
conceal it in this monstrous pouch, thus adapted fo
singular purposes."* Now this extraordinary conf
tion is nothing more, say our philosophers, tha
result of habit; not of the habit or effort of a sing
lican, or of a single race of pelicans, but of a habi
petuated through a long series of generations.
pelican soon found the conveniency of reserving
mouth, when its appetite was glutted, the remain
its prey, which is fish. The fulness produced b
attempt of course stretched the skin which lies be
the under chaps, as being the most yielding part
mouth. Every distension increased the cavity.
original bird, and many generations which succ
him, might find difficulty enough in making the
answer this purpose: but future pelicans, entering
life with a pouch derived from their progenitors, of
siderable capacity, would more readily accelerate it
vance to perfection, by frequently pressing down the
with the weight of fish which it might now be mad
contain.

These, or of this kind, are the analogies relied up
Now, in the first place, the instances themselves are
authenticated by testimony; and in theory, to say
least of them, open to great objections. Who ever r
of camels without bunches, or with bunches less th
those with which they are at present usually formed?
bunch, not unlike the camel's, is found between t
shoulders of the buffalo; of the origin of which it is i
possible to give the account here given. In the seco

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* Goldsmith, vol. vi. p. 52.

hy should the application of water, which
romote and thicken the growth of feathers
dies and breasts of geese, and swans, and
owls, have divested of this covering the
es? The third instance, which appears to
le as any that can be produced, has this
t it is a singularity restricted to the species;
had its commencement in the cause and
have been assigned, the like conformation
cted to take place in other birds, which fed
ow comes it to pass, that the pelican alone
ntress, and her descendants the only in-
is curious resource? [57]

ment against the doctrine of *appetencies* may
ipon well-known facts. If the camel's bunch
n the animal, originally without any protu-
g his back affected by burthens imposed, it
iat human contrivance could alter the shape
i it most certainly cannot, as daily experience
iost domestic animals shows. No change of
immediately and directly, as by cutting, com-
ig, can be perpetuated in the breed. All we
ard to animals, and all that any animals can
to themselves, is indirectly, as by affecting
affect the proportions of their parts, as bone,
e effects of which changes will be perceived

re been observing only upon the fact; but
to be as the theory of appetencies assumes,—
mel's bunch has been formed by weight and
pelican's pouch by the food distending the
n other words, suppose (contrary to what we
he fact) that the changes induced in one ani-
a given time, are propagated and continue in
ts,—it is plain that the sceptical argument
y this concession. For how are such changes
ily by the process of generation. Nay, how
st effected? By the operation of physical
the constitution of matter. The quadruped's
bird's pouch, allowing the whole facts to be
it assumes it, are both originally formed and
wards by the means of the qualities with

But it is the less necessary to controvert the
themselves, as it is a straining of analogy be
limits of reason and credibility, to assert that b
beasts, and fish, with all their variety and comple
organisation, have been brought into their forms, a
tinguished into their several kinds and natures, b
same process (even if that process could be demonst
or had it ever been actually noticed) as might se
serve for the gradual generation of a camel's bunch,
pelican's pouch.

The solution, when applied to the works of n
generally, is contradicted by many of the phenom
and totally inadequate to others. The *ligament*
strictures, by which the tendons are tied down a
angles of the joints, could, by no possibility, be fo
by the motion or exercise of the tendons themselves
an appetency exciting these parts into action; or b
tendency arising therefrom. The tendency is al
other way: the *conatus* in constant opposition to
Length of time does not help the case at all, but th
verse. The *valves* also in the blood-vessels could
be formed in the manner which our theorist pro
The blood, in its right and natural course, has n
dency to form them. When obstructed or reflu
has the contrary. These parts could not grow
their use, though they had eternity to grow in.

which matter is endowed; and the inference of design
affected by the step thus added to the process of rea
It can manifestly make no difference to that inference
ther we hold that the bird's pouch is provided for its
sities by a conformation at all times belonging to it acc
to the constitution of the world, or by one superin
according to that same constitution. The utmost th
sceptical hypothesis can gain by such concessions as w
been supposing to be made, is that the form of the
was at one time less perfect than it now is. A
mark arises upon the conjecture of Laplace (in
have followed him) respecting the original ar
tions and longitudes of Jupiter's thr
of in another note.—(*See notes to*

nses of animals appear to me altogether in-
receiving the explanation of their origin which
y affords. Including under the word " sense "
and the perception, we have no account of
Iow will our philosopher get at *vision*, or make
How should the blind animal affect sight, of
id animals, we know, have neither conception
? Affecting it, by what operation of its will,
endeavour to see, could it so determine the
s body, as to inchoate the formation of an eye?
the eye formed, would the perception follow?
of the other senses. And this objection holds
scribe what you will to the hand of time, to
of habit, to changes too slow to be observed
r brought within any comparison which he is
ake of past things with the present; concede
please to these arbitrary and unattested sup-
how will they help you? Here is no incep-
laws, no course, no powers of nature which
present, nor any analogous to these, would
encement to a new sense. And it is in vain
how that might proceed, which could never

the senses to be the most inconsistent with the
before us, of any part of the animal frame.
parts are sufficiently so. The solution does not
e parts of animals, which have little in them
If we could suppose joints and muscles to be
formed by action and exercise, what action or
uld form a skull, and fill it with brains? No
e animal could determine the clothing of its
at *conatus* could give prickles to the porcupine
g, or to the sheep its fleece?
last place: What do these appetencies mean
ied to plants? I am not able to give a sig-
to the term, which can be transferred from
plants; or which is common to both. Yet a
ccessful organisation is found in plants, than
ns in animals. A solution is wanted for one,
the other.

Upon the whole, after all the schemes and of a reluctant philosophy, the necessary reso Deity. The marks of *design* are too stro gotten over. Design must have had a design designer must have been a person. That GOD.

CHAPTER XXIV.

OF THE NATURAL ATTRIBUTES OF THE DEITY.

is an immense conclusion, that there is a God; a
ceiving, intelligent, designing Being; at the head of
ation, and from whose will it proceeded. The *attri-
es* of such a Being, suppose his reality to be proved,
st be adequate to the magnitude, extent, and mul-
icity of his operations: which are not only vast
ond comparison with those performed by any other
ver; but, so far as respects our conceptions of them,
nite, because they are unlimited on all sides.

Yet the contemplation of a nature so exalted, how-
r surely we arrive at the proof of its existence, over-
elms our faculties. The mind feels its powers sink
ler the subject. One consequence of which is, that
n painful abstraction the thoughts seek relief in sen-
e images. Whence may be deduced the ancient, and
ost universal propensity to idolatrous substitutions.
ey are the resources of a labouring imagination. False
gions usually fall in with the natural propensity;
e religions, or such as have derived themselves from
true, resist it.

t is one of the advantages of the revelations which we
nowledge, that, whilst they reject idolatry with its
ny pernicious accompaniments, they introduce the
ity to human apprehension, under an idea more per-
al, more determinate, more within its compass, than
theology of nature can do. And this they do by re-
senting him exclusively under the relation in which
stands to ourselves; and, for the most part, under
e precise character, resulting from that relation, or
n *the history of his* providences: which method suits

the span of our intellects much better than the universality which enters into the idea of God, as deduced from the views of nature. When, therefore, these representations are well founded in point of authority (for all depends upon that), they afford a condescension to the state of our faculties, of which they, who have most reflected on the subject, will be the first to acknowledge the want and the value.

Nevertheless, if we be careful to imitate the documents of our religion, by confining our explanations to what concerns ourselves, and do not affect more precision in our ideas than the subject allows of, the several terms which are employed to denote the attributes of the Deity may be made, even in natural religion, to bear a sense consistent with truth and reason, and not surpassing our comprehension.

These terms are,—Omnipotence, omniscience, omnipresence, eternity, self-existence, necessary existence, spirituality.

"Omnipotence," "omniscience," "infinite" power, "infinite" knowledge, are *superlatives*; expressing our conception of these attributes in the strongest and most elevated terms which language supplies. We ascribe power to the Deity under the name of "omnipotence," the strict and correct conclusion being, that a power which could create such a world as this is, must be, beyond all comparison, greater than any which we experience in ourselves, than any which we observe in other visible agents; greater also than any which we can want, for our individual protection and preservation, in the Being upon whom we depend. It is a power, likewise, to which we are not authorised, by our observation or knowledge, to assign any limits of space or duration.

Very much of the same sort of remark is applicable to the term "omniscience," infinite knowledge, or infinite wisdom. In strictness of language, there is a difference between knowledge and wisdom; wisdom always supposing action, and action directed by it. With respect to the first, viz. *knowledge*, the Creator must know, *intimately*, the constitution and properties of the things he created: which seems also to imply a fore- edge of their action upon one another, and of their es; at least, so far as the same result from trains of al and necessary causes. His omniscience also, as respects things present, is deducible from his , as an intelligent being, joined with the extent, or the universality, of his operations. Where he e is: and where he is, he perceives. The *wisdom* Deity, as testified in the works of creation, sur- all idea we have of wisdom, drawn from the t intellectual operations of the highest class of in- nt beings with whom we are acquainted; and, is of the chief importance to us, whatever be its ss or extent, which it is evidently impossible that uld be able to determine, it must be adequate to nduct of that order of things under which we live. his is enough. It is of very inferior consequence, at terms we express our notion, or rather our ad- n, of this attribute. The terms, which the piety e usage of language have rendered habitual to us, e as proper as any other. We can trace this attri- uch beyond what is necessary for any conclusion to we have occasion to apply it. The degree of edge and power requisite for the formation of l nature cannot, with respect to us, be distin- d from infinite.[58]

divine "omnipresence" stands, in natural theo- upon this foundation:—In every part and place of iverse with which we are acquainted, we perceive ertion of a power, which we believe, mediately or

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is not perhaps quite correct to state that "*infinite*," lied to the Deity, means only a degree of power or n beyond all comparison greater than any such quali- ssessed by ourselves; and that this term, as well as *otence*," is merely a superlative. Those words also te the existence of the attributes in such a degree, that tent whatever of them being either presented to our tion, or conceived by our imagination, the Deity pos- hem in a still *greater degree*—a degree to which our *ion can affix no bounds.*

immediately, to proceed from the Deity. For instance: in what part or point of space, that has ever been explored, do we not discover attraction? In what regions do we not find light? In what accessible portion of our globe do we not meet with gravity, magnetism, electricity: together with the properties also and powers of organised substances, of vegetable or of animated nature? Nay, further, we may ask, What kingdom is there of nature, what corner of space, in which there is any thing that can be examined by us, where we do not fall upon contrivance and design? The only reflection perhaps which arises in our minds from this view of the world around us is, that the laws of nature everywhere prevail; that they are uniform and universal. But what do you mean by the laws of nature, or by any law? Effects are produced by power, not by laws. A law cannot execute itself. A law refers us to an agent. Now an agency so general, as that we cannot discover its absence, or assign the place in which some effect of its continued energy is not found, may, in popular language at least, and, perhaps, without much deviation from philosophical strictness, be called universal: and, with not quite the same, but with no inconsiderable propriety, the person or Being, in whom that power resides, or from whom it is derived, may be taken to be *omnipresent*. He who upholds all things by his power, may be said to be every where present.

This is called a virtual presence. There is also what metaphysicians denominate an essential ubiquity; and which idea the language of Scripture seems to favour: but the former, I think, goes as far as natural theology carries us.[59]

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[59] Upon this confessedly abstruse subject some statements will be found in the Appendix. The three doctrines are—ubiquity by *diffusion*, *virtual* ubiquity, or that of power only, and ubiquity of *essence*. The last is expressed thus, to the exclusion of the second, by Sir I. Newton, in the Schol. Gen. to the Principia:—"Omnipræsens est non per *virtutem* solam sed etiam per *substantiam*; nam virtus sine substantia *subsistere non* potest." It is perhaps hardly correct to say

nity" is a negative idea, clothed with a positive
[t supposes, in that to which it is applied, a pre-
tence; and is the negation of a beginning or an
at existence. As applied to the Deity, it has
controverted by those who acknowledge a
all. Most assuredly, there never was a time in
thing existed, because that condition must have
l. The universal *blank* must have remained;
could rise up out of it; nothing could ever have
ince; nothing could exist now. In strictness,
we have no concern with duration prior to that
isible world. Upon this article therefore of
it is sufficient to know that the contriver ne-
existed before the contrivance.
existence" is another negative idea, viz. the
of a preceding cause, as of a progenitor, a
a author, a creator.[60]

ral Theology carries us not to the idea of Essential
Dr. Clarke makes Essential Ubiquity one part of
ısion from the argument *à priori;* and though his
s (see Chev. Ramsay, book i. prop. 8. Schol.)
ıim with adopting the Diffusive Ubiquity, he is
ɔt subject to this observation. The followers of
who maintained Virtual Ubiquity, are ably com-
l the Essential Ubiquity defended by Dr. Hancock
ecture, vol. ii. p. 222), upon arguments drawn from
eligion. We are here, it is to be observed, only
ɔf the idea or doctrine itself having been attained
nt of Revelation; and not inquiring how far those
s of unassisted reason have enforced the belief of it,
nade it comprehensible. Descartes (Principia I.
s not enumerate Ubiquity at all among the attri-
ess in so far as it may be included under infinite
generally ascribed.—(I. xxii. xxvii., II. xxxvi.,

existent means, in any intelligible sense, only un-
ıdependent, eternal. The ancient doctrine of *Self-*
it goes beyond the mere negative sense, is abso-
ntelligible, or, to use Dr. Clarke's words, "an ex-
radiction."

"Necessary existence" means demonstrable existence.[61]

"Spirituality" expresses an idea, made up of a negative part, and of a positive part. The negative part consists in the exclusion of some of the known properties of matter, especially of solidity, of the *vis inertiæ*, and of gravitation. The positive part comprises perception, thought, will, power, *action*, by which last term is meant the origination of motion; the quality, perhaps, in which resides the essential superiority of spirit over matter, "which cannot move, unless it be moved; and cannot but move, when impelled by another."* I apprehend that there can be no difficulty in applying to the Deity both parts of this idea.

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[61] *Necessary* properly means demonstrable in such a way, that the contrary involves a contradiction, and is inconceivable. Dr. Paley here uses the word demonstrable *per se* in this sense, for which he has the authority of several metaphysical writers.

* Bishop Wilkins's Principles of Natural Religion, p. 106.

CHAPTER XXV.

OF THE UNITY OF THE DEITY.

r the "Unity of the Deity," the proof is, the
rmity of plan observable in the universe. The unive
elf is a system; each part either depending upon oth
rts, or being connected with other parts by some co
on law of motion, or by the presence of some commo
bstance. One principle of gravitation causes a ston
drop towards the earth, and the moon to wheel roun
. One law of attraction carries all the different planets
out the sun.[62] This philosophers demonstrate. There

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[62] Bishop Brinkley considers the subject of nebulæ and
ble stars "as hardly yet sufficiently investigated" for
rding grounds of additional illustration to the cultivator
Natural Theology; and it is much to be regretted that he,
his account, abandoned the design, which he says he had
e time formed, of adding some notes upon this branch of
nomical science. The Appendix will contain a refer-
to this subject, particularly to the additional argument
from the revolution of double stars in favour of the
sal extension of gravitation.
fact of the heavenly bodies which form our system all
in the same direction of revolution, is deserving of
pest attention when we consider that it leads to the
portant result of the stability of the system explained
hap. xxii., notes); and that it is one of innumerable
nents which might have been made, and none of
uld have led to this result. In any other case equal
imaginary roots, or both, must have found their
the equation from which the law of stability is
(*Méc. Cél.* l. ii. c. 7, s. 55, 57, and liv. xv. c. 1.)
me profound geometrician has shown, in another
e calculus of probabilities, that it is above fou

are also other points of agreement amongst them, which may be considered as marks of the identity of their origin and of their intelligent Author. In all are found the conveniency and stability derived from gravitation. They all experience vicissitudes of days and nights, and changes of season. They all, at least Jupiter, Mars, and Venus, have the same advantages from their atmosphere as we have. In all the planets, the axes of rotation are permanent. Nothing is more probable than that the same attracting influence, acting according to the same rule, reaches to the fixed stars: but, if this be only probable, another thing is certain, *viz.* that the same element of light does. The light from a fixed star affects our eyes in the same manner, is refracted and reflected according to the same laws, as the light of a candle. The velocity of the light of the fixed stars is also the same as the velocity of the light of the sun, reflected from the satellites of Jupiter. The heat of the

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millions of millions to one in favour of the forty-three motions from west to east (including rotation as well as revolution and the motions of the sun and of the rings, as well as of the planets and satellites) having been directed by one original or First Cause; and by the same calculus he has shown the probability of the sun's rising again on the morrow of any given day, to be not much more than 1,800,000 to one, or, in other words, that this event is above two million times less probable than the truth of the position that the motions in our system were designed by one First Cause. This illustrious philosopher has been censured for not drawing in terms the conclusion to which his sublime researches, with those of Lagrange, have led the way, and at which he must himself have arrived,—that a Supreme Intelligence alone could have formed this magnificent and stable system. His reason for abstaining from indulging in such contemplations probably was that his work is purely mathematical, and that this would have been a digression into another science. But the reason is not sufficient, and the omission must ever be lamented as a defect in a work so nearly perfect. Mr. Whewell has made some ingenious *strictures upon* this subject in his able and learned *Bridgewater Treatise*, b. iii. c. 5 and 6.

un, in kind, differs nothing from the heat of a coal ire.[63]

In our own globe, the case is clearer. New countries re continually discovered, but the old laws of nature are lways found in them: new plants, perhaps, or animals,

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[63] The law by which the distances of the planets are reguated was referred to in a note by Bishop Brinkley to the 2d chapter, and affords an evidence of unity of design not o be passed over. It is this nearly, but not exactly. Form series of numbers, each consisting of the number 4 added o the number 3, but to the number 3 multiplied successively y 0, 1, 2, 4, 8, 16, and the other powers of 2: the mean istance of Mercury being 4, this series will represent the ean distances of the other planets successively. Taking he four newly-discovered planets between Mars and Jupiter s one—the distances of Venus, the Earth, and Jupiter, oincide with the series exactly; the others slightly differ. hus—

Mercury by the supposition	4		4
Venus by the theory	7	by observation	7
Earth	10		10
Mars	16		15
New planets	28		27
Vesta		23·73	
Juno		26·67	
Ceres		27·67	
Pallas		27·68	
Jupiter	52		52
Saturn	100		95
Uranus	196		192

“We cannot but remark,” says Bishop Brinkley, “the ear agreement of the law with the exact mean distances, nd cannot hesitate to pronounce that those were assigned ccording to a law, although we are entirely ignorant of the xact law and of the reason for that law.”

This sentence derives a peculiar, though a painful interest om the circumstance of its being in all likelihood the last ritten by this profound and accomplished astronomer, on ubjects connected with his favourite study. It closed the ommunication received from him, which was dated at loyne, June 25, *1835; and he* died at Dublin in less than *hree months after (September 14).*

but always in company with plants and animals which we already know; and always possessing many of the same general properties. We never get amongst such original, or totally different, modes of existence, as to indicate, that we are come into the province of a different Creator, or under the direction of a different will. In truth, the same order of things attends us wherever we go. The elements act upon one another, electricity operates, the tides rise and fall, the magnetic needle elects its position, in one region of the earth and sea, as well as in another. One atmosphere invests all parts of the globe, and connects all; one sun illuminates, one moon exerts its specific attraction upon all parts. If there be a variety in natural effects, as, *e. g.* in the tides of different seas, that very variety is the result of the same cause, acting under different circumstances. In many cases this is proved; in all, is probable.

The inspection and comparison of *living* forms add to this argument examples without number. Of all large terrestrial animals the structure is very much alike; their senses nearly the same; their natural functions and passions nearly the same; their viscera nearly the same, both in substance, shape, and office: digestion, nutrition, circulation, secretion, go on in a similar manner in all; the great circulating fluid is the same; for, I think, no difference has been discovered in the properties of *blood*, from whatever animal it be drawn. The experiment of transfusion proves that the blood of one animal will serve for another. The *skeletons* also of the larger terrestrial animals show particular varieties, but still under a great general affinity. The resemblance is somewhat less, yet sufficiently evident, between quadrupeds and birds. They are all alike in five respects, for one in which they differ.

In *fish*, which belong to another department, as it were, of nature, the points of comparison become fewer. But we never lose sight of our analogy: *e.g.* we still meet with a stomach, a liver, a spine; with bile and blood; with teeth; with eyes (which eyes are only slightly varied from our own, and which variation, in *truth, demonstrates*, not an interruption, but a continuaf the same exquisite plan; for it is the adaptation organ to the element, *viz.* to the different refrac- light passing into the eye out of a denser medium). rovinces, also, themselves of water and earth, are ted by the species of animals which inhabit both; o by a large tribe of aquatic animals, which closely le the terrestrial in their internal structure; I he cetaceous tribe, which have hot blood, respiring bowels, and other essential parts, like those of imals. This similitude, surely, bespeaks the same n and the same Creator.

cts and *shell-fish* appear to me to differ from other of animals the most widely of any. Yet even besides many points of particular resemblance, xists a general relation of a peculiar kind. It is ation of inversion; the law of contrariety: namely, hereas, in other animals, the bones, to which the s are attached, lie *within* the body, in insects and sh they lie on the *outside* of it. The shell of a performs to the animal the office of a *bone*, by ng to the tendons that fixed basis or immoveable without which, mechanically, they could not e crust of an insect is its shell, and answers the ose. The shell also of an oyster stands in the *bone;* the bases of the muscles being fixed to same manner as, in other animals, they are fixed es. All which (under wonderful varieties, in- adaptations of form) confesses an imitation, a ce, a carrying on, of the same plan.

ervations here made are equally applicable to , I think, unnecessary to be pursued. It is a circumstance, and also sufficient to prove all ntend for, that, in this part likewise of or- re, we perceive a continuation of the *sexual*

wever it is, that the whole argument for ity goes no farther than to an unity of

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rdinary discoveries in geology made since by the study of fossil osteology, by no

It may likewise be acknowledged, that nc which we are in possession of, exclude the subordinate agents. If such there be, they presiding, a controlling will; because they ac to certain general restrictions, by certain coı and, as it should seem, upon a general plaı such agents, and different ranks and classes of them, may be employed.[65]

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means impair his argument as to Unity when sidered. These will be fully discussed in th and they throw material light upon other braı subject.

[65] Addison, a person of practical understa temperament, and widely removed from all (Spectator, No. 110), states very plainly his beli not in the religious and philosophical sense of agents, adopted by Dr. Paley, but in the popu ghosts. He rests his opinion, as Dr. Johnson di inclination towards the same belief, upon the testimony. Respecting witchcraft, he elsewheı expresses the inclination of his opinion in favou rally and abstractedly; but refusing all credit t instances. The feeling which dictates such a d believe in a spiritual world is natural, as well but it may be questioned if religion does not l as it can gain by indulging in it.

CHAPTER XXVI.

OF THE GOODNESS OF THE DEITY.

The proof of the *divine goodness* rests upon two propositions: each, as we contend, capable of being made out by observations drawn from the appearances of nature.

The first is, "that in a vast plurality of instances in which contrivance is perceived, the design of the contrivance is *beneficial*."

The second, "that the Deity has superadded *pleasure* to animal sensations beyond what was necessary for any other purpose, or when the purpose, so far as it was necessary, might have been effected by the operation of pain."

First, "in a vast plurality of instances in which contrivance is perceived, the design of the contrivance is *beneficial*."

No productions of nature display contrivance so manifestly as the parts of animals; and the parts of animals have all of them, I believe, a real, and, with very few exceptions, all of them a known and intelligible subserviency to the use of the animal. Now, when the multitude of animals is considered, the number of parts in each, their figure and fitness, the faculties depending upon them, the variety of species, the complexity of structure, the success, in so many cases, and felicity of the result, we can never reflect, without the profoundest adoration, upon the character of that Being from whom all these things have proceeded: we cannot help acknowledging what an exertion of benevolence creation was; of a benevolence how minute in its care, how vast in its comprehension!

When we appeal to the parts and faculties of
and to the *limbs and senses* of animals in parti

state, I conceive, the proper medium of proof for the conclusion which we wish to establish. I will not say that the insensible parts of nature are made solely for the sensitive parts: but this I say, that when we consider the benevolence of the Deity, we can only consider it in relation to sensitive being. Without this reference, or referred to anything else, the attribute has no object, the term has no meaning. Dead matter is nothing. The parts, therefore, especially the limbs and senses, of animals, although they constitute in mass and quantity a small portion of the material creation, yet, since they alone are instruments of perception, they compose what may be called the whole of visible nature, estimated with a view to the disposition of its Author. Consequently, it is in *these* that we are to seek his character. It is by these that we are to prove that the world was made with a benevolent design.

Nor is the design abortive. It is a happy world after all. The air, the earth, the water, teem with delighted existence. In a spring noon or a summer evening, on whichever side I turn my eyes, myriads of happy beings crowd upon my view. "The insect youth are on the wing." Swarms of new-born *flies* are trying their pinions in the air. Their sportive motions, their wanton mazes, their gratuitous activity, their continual change of place without use or purpose, testify their joy and the exultation which they feel in their lately discovered faculties. A *bee* amongst the flowers in spring is one of the most cheerful objects that can be looked upon. Its life appears to be all enjoyment, so busy and so pleased; yet it is only a specimen of insect life, with which, by reason of the animal being half domesticated, we happen to be better acquainted than we are with that of others. The *whole-winged* insect tribe, it is probable, are equally intent upon their proper employments, and, under every variety of constitution, gratified, and perhaps equally gratified, by the offices which the Author of their nature has assigned to them. But the atmosphere is not the only scene of enjoyment for the insect race. Plants are covered with aphides, greedily sucking their juices, and

y, as it should seem, in the act of sucking It
› doubted but that this is a state of gratification.
e should fix them so close to the operation, and
Other species are *running about*, with an
ı their motions which carries with it every mark
ıre. Large patches of ground are sometimes
red with these brisk and sprightly natures. If
o what the *waters* produce, shoals of the fry of
ıent the margins of rivers, of lakes, and of the
. These are so happy, that they know not
do with themselves. Their attitudes, their
their leaps out of the water, their frolics in it
[have noticed a thousand times with equal
and amusement), all conduce to show their ex-
ırits, and are simply the effects of that excess.
by the sea-side, in a calm evening, upon a
ıre, and with an ebbing tide, I have frequently
the appearance of a dark cloud, or rather very
st, hanging over the edge of the water, to the
erhaps, of half a yard, and of the breadth of
ree yards, stretching along the coast as far as
ould reach, and always retiring with the water.
is cloud came to be examined, it proved to be
else than so much space filled with young
in the act of bounding into the air from the
ıargin of the water, or from the wet sand. If
ɔn of a mute animal could express delight, it
if they had meant to make signs of their hap-
ıey could not have done it more intelligibly.
then, what I have no doubt of, each individual
umber to be in a state of positive enjoyment;
ım, collectively, of gratification and pleasure
here before our view ![66]
oung of all animals appear to me to receive

hese considerations it must be added, that the lives
ıimals may be only apparently short. If time is
succession of ideas, then, as Soame Jenyns has
the insect that flutters for a single summer's day
ality live as long as the tortoise that breathes for a

pleasure simply from the exercise of their limbs bodily faculties, without reference to any end tc attained, or any use to be answered by the exertion. child, without knowing anything of the use of langu is in a high degree delighted with being able to sp Its incessant repetition of a few articulate sounds, perhaps, of the single word which it has learnt to nounce, proves this point clearly. Nor is it less ple with its first successful endeavours to walk, or rath run (which precedes walking), although entirely i rant of the importance of the attainment to its fu life, and even without applying it to any present pose. A child is delighted with speaking, wit having anything to say, and with walking, wit knowing where to go. And, prior to both these, disposed to believe that the waking hours of infancy agreeably taken up with the exercise of vision, or haps, more properly speaking, with learning to see.

But it is not for youth alone that the great Pare creation hath provided. Happiness is found with purring cat, no less than with the playful kitten; in arm-chair of dozing age, as well as in either the spr liness of the dance, or the animation of the chase. novelty, to acuteness of sensation, to hope, to ardo pursuit, succeeds, what is, in no inconsiderable de an equivalent for them all, "perception of ease." H is the exact difference between the young and the The young are not happy but when enjoying pleas the old are happy when free from pain. And this stitution suits with the degrees of animal power w they respectively possess. The vigour of youth w be stimulated to action by impatience of rest; whil the imbecility of age, quietness and repose become tive gratifications. In one important respect the a tage is with the old. A state of ease is, gene speaking, more attainable than a state of pleasure. constitution, therefore, which can enjoy ease, is pı able to that which can taste only pleasure. This *perception* of ease oftentimes renders old age a conc *of great* comfort, especially when riding at its

busy or tempestuous life. It is well described by
au, to be the interval of repose and enjoyment
n the hurry and the end of life. How far the
ause extends to other animal natures cannot be
of with certainty. The appearance of satisfaction
hich most animals, as their activity subsides, seek
oy rest, affords reason to believe that this source
fication is appointed to advanced life, under all or
its various forms. In the species with which we
t acquainted, namely, our own, I am far, even as
rver of human life, from thinking that youth is its
t season, much less the only happy one: as a
an, I am willing to believe that there is a great
truth in the following representation given by a
ous writer, as well as excellent man:*—"To the
ent and virtuous, old age presents a scene of tran-
joyments, of obedient appetite, of well-regulated
ns, of maturity in knowledge, and of calm pre-
n for immortality. In this serene and dignified
laced as it were on the confines of two worlds,
nd of a good man reviews what is past with the
cency of an approving conscience, and looks for-
with humble confidence in the mercy of God, and
evout aspirations, towards his eternal and ever-
ing favour."

it is seen in different stages of the same life, is still
xemplified in the lives of different animals. Animal
ents are infinitely *diversified*. The modes of life,
h the organisation of different animals respectively
ines them, are not only of various, but of opposite
Yet each is happy in its own. For instance:
of prey live much alone; animals of a milder
ution in society. Yet the herring, which lives in
and the sheep, which lives in flocks, are not more
in a crowd, or more contented amongst their com-
s, than is the pike or the lion, with the deep soli-
f the pool or the forest.

it will be said that the instances which we have

ther's *Instructions*, by Dr. Percival, of Manchester, here brought forward, whether of vivacity or repose, or of apparent enjoyment derived from either, are picked and favourable instances. We answer, first, that they are instances, nevertheless, which comprise large provinces of sensitive existence; that every case which we have described is the case of millions. At this moment, in every given moment of time, how many myriads of animals are eating their food, gratifying their appetites, ruminating in their holes, accomplishing their wishes, pursuing their pleasures, taking their pastimes! In each individual, how many things must go right for it to be at ease; yet how large a proportion out of every species is so in every assignable instant! Secondly, we contend, in the terms of our original proposition, that throughout the whole of life, as it is diffused in nature, and as far as we are acquainted with it, looking to the average of sensations, the plurality and the preponderancy is in favour of happiness by a vast excess. In our own species, in which, perhaps, the assertion may be more questionable than any other, the prepollency of good over evil, of health, for example, and ease, over pain and distress, is evinced by the very notice which calamities excite. What inquiries does the sickness of our friends produce! what conversation their misfortunes! This shows that the common course of things is in favour of happiness; that happiness is the rule, misery the exception. Were the order reversed, our attention would be called to examples of health and competency, instead of disease and want.

One great cause of our insensibility to the goodness of the Creator, is the very *extensiveness* of his bounty. We prize but little what we share only in common with the rest, or with the generality of our species. When we hear of blessings, we think forthwith of successes, of prosperous fortunes, of honours, riches, preferments, i. e. of those advantages and superiorities over others, which we happen either to possess, or to be in pursuit of, or to covet. The common benefits of our nature entirely escape us. Yet these are the great things. These constitute what most properly ought to be accounted blessof Providence; what alone, if we might so speak, 'orthy of its care. Nightly rest and daily bread, the ary use of our limbs, and senses, and understandings, ifts which admit of no comparison with any other. because almost every man we meet with possesses , we leave them out of our enumeration. They no sentiment; they move no gratitude. Now, a is our judgment perverted by our selfishness. A ng ought in truth to be the *more* satisfactory—the y at least of the donor is rendered more conspicuous its very diffusion, its commonness, its cheapness; falling to the lot and forming the happiness of the bulk and body of our species, as well as of our-. Nay, even when we do not possess it, it ought matter of thankfulness that others do. But we a different way of thinking. We court distinction. is not the worst; we *see* nothing but what has dis-n to recommend it. This necessarily contracts ews of the Creator's beneficence within a narrow ss, and most unjustly. It is in those things which common as to be no distinction, that the amplitude Divine benignity is perceived.

pain, no doubt, and privations exist in numerous ces, and to a great degree, which collectively be very great, if they were compared with any thing than with the mass of animal fruition. For pplication, therefore, of our proposition to that state of things which these exceptions induce, two re necessary, and both, I think, just and fair rules. s, that we regard those effects alone which are panied with proofs of intention; the other, that we cannot resolve all appearances into benevolence ign, we make the few give place to the many; the o the great; that we take our judgment from a and decided preponderancy, if there be one.[67]

This passage, with others which afterwards occur in ork, as well as the part here quoted from the author's Philosophy, has been, it should seem, somewhat mis-stood by several excellent authors, who have treated s *if he were denying the* existence of evil; and have

I crave leave to transcribe into this place what I have said upon this subject in my Moral Philosophy:—

"When God created the human species, either he wished their happiness, or he wished their misery, or he was indifferent and unconcerned about either.

"If he had wished our misery, he might have made sure of his purpose, by forming our senses to be so many sores and pains to us, as they are now instruments of gratification and enjoyment: or by placing us amidst objects so ill suited to our perceptions, as to have continually offended us, instead of ministering to our refreshment and delight. He might have made, for example, every thing we tasted, bitter; every thing we saw, loathsome; every thing we touched, a sting; every smell, a stench; and every sound, a discord.

"If he had been indifferent about our happiness or misery, we must impute to our good fortune (as all design by this supposition is excluded) both the capacity of our senses to receive pleasure, and the supply of external objects fitted to produce it.

"But either of these, and still more both of them, being too much to be attributed to accident, nothing remains but the first supposition, that God, when he created the human species, wished their happiness; and

referred, though without any sceptical view, to the old dilemma of the Epicureans, stated by Lactantius:—"Aut vult, et non potest; aut potest et non vult tollere mala." But Dr. Paley's whole discourse upon this subject must be taken as an attempt, and a successful one, to diminish the apparent amount of evil, by showing that many of the things accounted evils are less bad than they seem to be. He explains the deductions which are fairly to be made; he shows the compensations which exist; he proves that out of evil good frequently arises. Having done this, evil still remains, but in an amount exceedingly reduced; and this remaining portion is that concerning which alone the question arises. All that follows of the text must be read with this view; and it must be admitted that nothing can be more legitimate than the scope of the reasoning employed if regarded in this light. Viewed in any other, it would be liable to the objections which have been urged against it.

for them the provision which he has made, with iew and for that purpose.

'he same argument may be proposed in different ; *thus:* Contrivance proves design; and the pre- iant tendency of the contrivance indicates the dis- on of the designer. The world abounds with vances; and all the contrivances which we are inted with are directed to beneficial purposes. no doubt, exists; but is never, that we can per- the *object* of contrivance. Teeth are contrived to ot to ache; their aching now and then is incidental contrivance, perhaps inseparable from it: or even, will, let it be called a defect in the contrivance; is not the object of it. This is a distinction which leserves to be attended to. In describing imple- of husbandry, you would hardly say of the sickle, t is made to cut the reaper's hand: though from nstruction of the instrument, and the manner of it, this mischief often follows. But if you had on to describe instruments of torture, or execution, engine, you would say, is to extend the sinews; dislocate the joints; this to break the bones; this rch the soles of the feet. Here, pain and misery e very objects of the contrivance. Now, nothing s sort is to be found in the works of nature. We discover a train of contrivance to bring about an urpose. No anatomist ever discovered a system of isation calculated to produce pain and disease; or, plaining the parts of the human body, ever said, to irritate; this to inflame; this duct is to convey ravel to the kidneys; this gland to secrete the r which forms the gout: if by chance he come at of which he knows not the use, the most he can that it is useless; no one ever suspects that it is ere to incommode, to annoy, or to torment."

TWO CASES which appear to me to have the most lty in them, as forming the most of the appearance eption to the representation here given, are those *omous* animals, and of animals *preying* upon one *r.* *These properties* of animals, wherever they are found, must, I think, be referred to design there is in all cases of the first, and in most ca second, an express and distinct organisation for the producing of them. Under the first fangs of vipers, the stings of wasps and scorpic clearly intended for their purpose, as any ani ture is for any purpose the most incontestably And the same thing must, under the second acknowledged of the talons and beaks of bir tusks, teeth, and claws of beasts of prey; of t mouth, of the spider's web, and of numberles of offence belonging to different tribes of vor sects. We cannot, therefore, avoid the diff saying, that the effect was not intended. question open to us is, whether it be ultima From the confessed and felt imperfection of ledge, we ought to presume, that there may quences of this œconomy which are hidden from the benevolence which pervades the gene of nature, we ought also to presume, that th quences, if they could enter into our calculati turn the balance on the favourable side. Bot contend to be reasonable presumptions. Not presumptions, if these two cases were the c which nature presented to our observation; b able presumptions under the reflection, that th question are combined with a multitude of i all proceeding from the same author, and a these, directed to ends of undisputed utility. vindications, however, of this œconomy, whi able to assign, such as most extenuate the diff the following.

With respect to *venomous* bites and stings, observed,—

1. That, the animal itself being regarded, t complained of is *good;* being conducive, in all the defence of the animal; in some cases, to the of its prey; and in some, probably, to the kil when caught, by a mortal wound, inflicted in t *to the stomach,* which may be no less merci

in, than salutary to the devourer. In the viper, for
nce, the poisonous fang may do that which, in other
nls of prey, is done by the crush of the teeth. Frogs
mice might be swallowed alive without it.

But it will be said, that this provision, when it
es to the case of bites, deadly even to human bodies,
to those of large quadrupeds, is greatly overdone;
it might have fulfilled its use, and yet have been
h less deleterious than it is. Now I believe the case
ites which produce death in large animals (of stings
ink there are none) to be very few. The experi-
ts of the Abbé Fontana, which were numerous, go
gly to the proof of this point. He found that it
ired the action of five exasperated vipers to kill a
of a moderate size; but that to the killing of a
se, or a frog, a single bite was sufficient; which
es with the use which we assign to the faculty.
Abbé seemed to be of opinion, that the bite even
e rattlesnake would not usually be mortal; allowing,
ever, that in certain particularly unfortunate cases,
hen the puncture had touched some very tender part,
ced a principal nerve, for instance, or, as it is said,
more considerable lymphatic vessel, death might
dily ensue.

It has been, I think, very justly remarked, con-
ing serpents, that, whilst only a few species possess
venomous property, that property guards the whole
. The most innocuous snake is avoided with as
h care as a viper. Now the terror with which large
als regard this class of reptiles is its protection; and
terror is founded on the formidable revenge which
w of the number, compared with the whole, are
ble of taking. The species of serpents, described
innæus, amount to two hundred and eighteen, of
h thirty-two only are poisonous.

It seems to me, that animal constitutions are pro-
d, not only for each element, but for each state of
elements, i. e. for every climate, and for every tem-
ture; and that part of the mischief compl
s from animals (the human animal most es

occupying situations upon the earth which do not belong to them, nor were ever intended for their habitation. The folly and wickedness of mankind, and necessities proceeding from these causes, have driven multitudes of the species to seek a refuge amongst burning sands, whilst countries, blessed with hospitable skies, and with the most fertile soils, remain almost without a human tenant. We invade the territories of wild beasts and venomous reptiles, and then complain that we are infested by their bites and stings. Some accounts of Africa place this observation in a strong point of view. "The deserts," says Adanson, "are entirely barren, except where they are found to produce serpents; and in such quantities, that some extensive plains are almost entirely covered with them." These are the natures appropriated to the situation. Let them enjoy their existence; let them have their country. Surface enough will be left to man, though his numbers were increased a hundred-fold, and left to him, where he might live exempt from these annoyances.

The SECOND CASE, *viz.* that of animals *devouring* one another, furnishes a consideration of much larger extent. To judge whether, as a general provision, this can be deemed an *evil*, even so far as we understand its consequences, which, probably, is a partial understanding, the following reflections are fit to be attended to.[68]

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[68] The subject of apparently conflicting contrivances, including conflicting instincts, as well as apparently imperfect contrivances and instincts, will be considered at large in the Appendix. The progress of science is constantly diminishing the number of such instances, as far as our ignorance of design goes. That some conflict will continue,—in other words, that evil to a certain amount will, after all deductions, be found to exist, cannot be doubted. But that an immense preponderance of good exists in every department of nature, both of matter and of mind, is so clear, that, arguing as we do on every other subject, we have a right to impute the perception of any evil at all to our own ignorance, and to conclude that, if we knew the whole system, and could extend our comprehension to the entire plan of *creation*, we should no longer believe there was evil at all.

1. Immortality upon this earth is out of the questio Without death there could be no generation, no sexe no parental relation, *i. e.* as things are constituted, n animal happiness. The particular duration of life, a signed to different animals, can form no part of the ob jection; because, whatever that duration be, whilst remains finite and limited, it may always be asked, wh it is no longer. The natural age of different anima varies, from a single day to a century of years. No a count can be given of this; nor could any be given, wha ever other proportion of life had obtained amongst the

The term then of life in different animals being th same as it is, the question is, what mode of taking it awa is the best even for the animal itself.

Now, according to the established order of natur (which we must suppose to prevail, or we cannot reaso at all upon the subject), the three methods by which li is usually put an end to are acute diseases, decay, an violence. The simple and natural life of *brutes* is n often visited by acute distempers; nor could it be deeme an improvement of their lot if they were. Let it b considered, therefore, in what a condition of sufferin and misery a brute animal is placed which is left t perish by *decay*. In human sickness or infirmity, the is the assistance of man's rational fellow-creatures, if n to alleviate his pains, at least to minister to his necess ties, and to supply the place of his own activity. brute, in his wild and natural state, does every thing f himself. When his strength, therefore, or his speed, his limbs, or his senses fail him, he is delivered ove either to absolute famine or to the protracted wretche ness of a life slowly wasted by the scarcity of food.

Of the different hypotheses to which we may have recour for explaining what we are unable legitimately to solve, t Probationary State is one, and is the one which appears tally best with the facts. It is hardly necessary to add th we are now, as throughout these notes, after the example the author, confining ourselves altogether to the intimatio received from natural reason and observation, unaid light of revelation.

it then to see the world filled with drooping, su nuated, half-starved, helpless, and unhelped animal you would alter the present system of pursuit and p

2. Which system is also to them the spring of m and activity on both sides. The pursuit of its forms the employment, and appears to constitute pleasure, of a considerable part of the animal creat The using of the means of defence, or flight, or pre tion, forms also the business of another part. And ev of this latter tribe, we have no reason to suppose th their happiness is much molested by their fears. Thei danger exists continually; and in some cases they see to be so far sensible of it, as to provide, in the best man ner they can, against it; but it is only when the attac is actually made upon them, that they appear to suff from it. To contemplate the insecurity of their conditio with anxiety and dread, requires a degree of reflectio which (happily for themselves) they do not possess. A *hare*, notwithstanding the number of its dangers and it enemies, is as playful an animal as any other.

3. But, to do justice to the question, the system animal *destruction* ought always to be considered in stri connexion with another property of animal nature, vi *superfecundity*. They are countervailing qualities. O subsists by the correction of the other. In treati therefore, of the subject under this view (which i believe, the true one), our business will be, first point out the advantages which are gained by the po in nature of a superabundant multiplication; and the show, that these advantages are so many reasons fo pointing that system of national hostilities, whic are endeavouring to account for.

In almost all cases, nature produces her supplie profusion. A single cod-fish spawns, in one sea greater number of eggs than all the inhabitants o land amount to. A thousand other instances of generation might be stated, which, though not e this, would carry on the increase of the specie rapidity which outruns calculation, and to an im able extent The advantages of such a constit two: first, that it tends to keep the world always full; whilst, secondly, it allows the proportion between the several species of animals to be differently modified, as different purposes require, or as different situations may afford for them room and food. Where this vast fecundity meets with a vacancy fitted to receive the species, there it operates with its whole effect; there it pours in its numbers and replenishes the waste. We complain of what we call the exorbitant multiplication of some troublesome insects; not reflecting, that large portions of nature might be left void without it. If the accounts of travellers may be depended upon, immense tracts of forests in North America would be nearly lost to sensitive existence, if it were not for *gnats*. "In the thinly inhabited regions of America, in which the waters stagnate and the climate is warm, the whole air is filled with crowds of these insects." Thus it is, that where we looked for solitude and death-like silence, we meet with animation, activity, enjoyment; with a busy, a happy, and a peopled world. Again: hosts of *mice* are reckoned amongst the plagues of the north-east part of Europe; whereas vast plains in Siberia, as we learn from good authority, would be lifeless without them. The Caspian deserts are converted by their presence into crowds of warrens. Between the Volga and the Yaik, and in the country of Hyrcania, the ground, says Pallas, is in many places *covered* with little hills, raised by the earth cast out in forming the burrows. Do we so envy these blissful abodes, as to pronounce the fecundity by which they are supplied with inhabitants to be an evil; a subject of complaint, and not of praise? Further; by virtue of this same superfecundity, what we term destruction becomes almost instantly the parent of life. What we call blights are oftentimes legions of animated beings, claiming their portion in the bounty of nature. What corrupts the produce of the earth to us, prepares it for them. And it is by means of their rapid multiplication, that they take possession of their pasture; a slow propagation would not meet the opportunity.

But in conjunction with the occasional use of this fruitfulness, we observe, also, that it allows the proportion between the several species of animals to be differently modified, as different purposes of utility may require. When the forests of America come to be cleared, and the swamps drained, our gnats will give place to other inhabitants. If the population of Europe should spread to the north and the east, the mice will retire before the husbandman and the shepherd, and yield their station to herds and flocks. In what concerns the human species, it may be a part of the scheme of Providence, that the earth should be inhabited by a shifting, or perhaps a circulating population. In this œconomy, it is possible that there may be the following advantages: When old countries are become exceedingly corrupt, simpler modes of life, purer morals, and better institutions, may rise up in new ones, whilst fresh soils reward the cultivator with more plentiful returns. Thus the different portions of the globe come into use in succession as the residence of man; and, in his absence, entertain other guests, which, by their sudden multiplication, fill the chasm. In domesticated animals, we find the effect of their fecundity to be, that we can always command *numbers;* we can always have as many of any particular species as we please, or as we can support. Nor do we complain of its excess; it being much more easy to regulate abundance, than to supply scarcity.

But then this *superfecundity*, though of great occasional use and importance, exceeds the ordinary capacity of nature to receive or support its progeny. All superabundance supposes destruction, or must destroy itself. Perhaps there is no species of terrestrial animals whatever, which would not overrun the earth, if it were permitted to multiply in perfect safety; or of fish, which would not fill the ocean: at least, if any single species were left to their natural increase without disturbance or restraint, the food of other species would be exhausted by their maintenance. It is necessary, therefore, that the effects of such prolific faculties be curtailed. In conjunction with other checks and limits, all subservient to the same *purpose,* are the *thinnings* which take place among animals, by their action upon one another. In some instances we ourselves experience, very directly, the use of these hostilities. One species of insects rids us of another species, or reduces their ranks. A third species, perhaps, keeps the second within bounds; and birds or lizards are a fence against the inordinate increase by which even these last might infest us. In other, more numerous, and possibly more important instances, this disposition of things, although less necessary or useful to us, and of course less observed by us, may be necessary and useful to certain other species; or even for the preventing of the loss of certain species from the universe: a misfortune which seems to be studiously guarded against. Though there may be the appearance of failure in some of the details of Nature's works, in her great purposes there never are. Her species never fail. The provision which was originally made for continuing the replenishment of the world has proved itself to be effectual through a long succession of ages.

What further shows, that the system of destruction amongst animals holds an express relation to the system of fecundity,—that they are parts indeed of one compensatory scheme,—is, that in each species the fecundity bears a proportion to the smallness of the animal, to the weakness, to the shortness of its natural term of life, and to the dangers and enemies by which it is surrounded. An elephant produces but one calf; a butterfly lays six hundred eggs. Birds of prey seldom produce more than two eggs: the sparrow tribe, and the duck tribe, frequently sit upon a dozen. In the rivers, we meet with a thousand minnows for one pike; in the sea, a million of herrings for a single shark. Compensation obtains throughout. Defencelessness and devastation are repaired by fecundity.

We have dwelt the longer on these considerations, because the subject to which they apply, namely, that of animals *devouring* one another, forms the chief, if not the only instance, in the works of the Deity, of an œconomy, stamped by marks of design, in which the character of utility can be called in question. The case of *venomous* animals is of much inferior *consequence* i case of prey, and, in some degree, is also *included* t it. To both cases it is probable that many *more* rea belong, than those of which we are in possession.

Our FIRST PROPOSITION, and that which we hitherto been defending, was, "that, in a vast plur of instances, in which *contrivance* is perceived, design of the contrivance is beneficial."

Our SECOND PROPOSITION is, "that the Deity added *pleasure* to animal sensations, beyond what necessary for any other purpose, or when the purp so far as it was necessary, might have been effected the operation of pain."[69]

This proposition may be thus explained: The c cities, which, according to the established course nature, are *necessary* to the support or preservatio an animal, however manifestly they may be the resul an organisation contrived for the purpose, ca deemed an act or a part of the same will as th decreed the existence of the animal itself; whether the creation proceeded from a benevole malevolent being, these capacities must have bee if the animal existed at all. Animal properties fore, which fall under this description, do not prove the goodness of God; they may prove the ence of the Deity; they may prove a high deg power and intelligence; but they do not prove his ness; forasmuch as they must have been found in creation which was capable of continuance, althoug is possible to suppose, that such a creation might been produced by a being whose views rested misery.

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[69] This is a most important consideration, and one w cannot be dwelt upon too constantly; and which assur will, by the contemplative and well-regulated mind, n be dwelt upon without experiencing the most pleasing salutary influence. It will be further illustrated in Appendix; but in this place it may be right to add tha induction of facts plainly shows the system of the univ to be governed upon the principle of inducement rather denouncement,—of reward more than of punishment; not only are sentient beings guided by the more kindly cess where the harsher would have sufficed, but there is r inducement employed, more pleasure superadded, tha even necessary to work the effect intended. It is as human lawgiver were to prefer rewarding his subjects obedience, rather than punishing them for contumacy; were then to add some bounty beyond what had been fo quite sufficient to ensure their compliance. It must be stantly borne in mind that there is not one single act formed by any animal, from man to the lowest insect in scale, in fulfilling the apparent ends of its creation, the formance of which might not have been secured as effectu by the pressure or by the apprehension of pain, as it no in so vast a number of instances, solicited by the enjoym *or the hope of* some gratification.

But there is a class of properties, which may be to be superadded from an intention expressly directe happiness; an intention to give a happy existence tinct from the general intention of providing the m of existence; and that is, of capacities for pleasur cases wherein, so far as the conservation of the indivi or of the species is concerned, they were not wante wherein the purpose might have been secured by operation of pain. The provision which is made variety of objects, not necessary to life, and ministe only to our pleasures; and the properties given to necessaries of life themselves, by which they contri to pleasure as well as preservation; show a fur design than that of giving existence.*

A single instance will make all this clear. Assu the necessity of food for the support of animal life, requisite that the animal be provided with organs f for the procuring, receiving, and digesting of its f It may also be necessary, that the animal be imp by its sensations to exert its organs. But the pai hunger would do all this. Why add pleasure to the act of eating; sweetness and relish to food? why a new and appropriate sense for the perception of the pleasure? Why should the juice of a peach, applied to the palate, affect the part so differently from what it does when rubbed upon the palm of the hand? This is a constitution which, so far as appears to me, can be resolved into nothing but the pure benevolence of the Creator. Eating is necessary; but the pleasure attending it is not necessary: and that this pleasure depends, not only upon our being in possession of the sense of taste, which is different from every other, but upon a particular state of the organ in which it resides, a felicitous adaptation of the organ to the object, will be confessed by any one, who may happen to have experienced that vitiation of taste which frequently occurs in fevers, when every taste is irregular, and every one bad.

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* See this topic considered in Dr. Balguy's Treatise the Divine Benevolence. This excellent author first, I t proposed it, and nearly in the terms in which it is stated. Some other observations also under this hea taken from that treatise.—*Note of the Author.*

In mentioning the gratifications of the palate, it may be said that we have made choice of a trifling example.[70]

[70] Neither this nor any other thing which our nature, physical or moral, is formed to relish, can be deemed trifling; and it is well observed afterwards that the very capacity of being pleased with what, by comparison with other things, are termed trivial matters, is itself a source of enjoyment provided for us by the divine beneficence. All men have within themselves the power of being amused or occupied, and interested—that is, pleased, gratified—with things which, until they make the attempt, they are disposed to regard as wholly incapable of affording any satisfaction. This is a most important source of enjoyment, and one more independent of external circumstances than they could believe who have never made the experiment. "Le goût (says Marmontel, *Mém.* I. 431) s'accommode aux objets dont il peut jouir; et cette sage maxime,

Quand on n'a pas ce que l'on aime,
Il faut aimer ce que l'on a,

est en effet non seulement une leçon de la nature, mais un moyen qu'elle se ménage pour nous procurer des plaisirs." The earlier and by far the most interesting part of his book abounds in illustrations of a kindred truth—the gratification *derived from* the humblest sources by those who have known

a not of that opinion. They afford a share of enjoy-
t to man; but to brutes, I believe that they are of
great importance. A horse at liberty passes a great
of his waking hours in eating. To the ox, the
p, the deer, and other ruminating animals, the plea-
is doubled. Their whole time almost is divided
veen browsing upon their pasture and chewing their
Whatever the pleasure be, it is spread over a
e portion of their existence. If there be animals,
as the lupous fish, which swallow their prey whole,
at once, without any time, as it should seem, for
er drawing out, or relishing, the taste in the mouth,
an improbable conjecture, that the seat of taste with
n is in the stomach; or, at least, that a sense of plea-
, whether it be taste or not, accompanies the disso-
n of the food in that receptacle, which dissolution in
ral is carried on very slowly? If this opinion be
t, they are more than repaid for the defect of palate.
feast lasts as long as the digestion.

seeking for argument, we need not stay to insist
the comparative importance of our example; for
observation holds equally of all, or of three at least,
e other senses. The necessary purposes of hearing
ht have been answered without harmony; of smell,
out fragrance; of vision, without beauty. Now,
the Deity had been indifferent about our happiness
nisery, we must impute to our good fortune (as all
gn by this supposition is excluded), both the capacity

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e other. "Nos galettes de sarrazin, humectées, toutes
antes, de ce bon beurre du Mont-d'or, étaient pour nous le
friand régal. Je ne sais pas quel mets nous eût paru
lleur que nos raves et nos châtaignes; et en hiver, lorsque
belles raves grillaient le soir à l'entour du foyer, ou que
s entendions bouillonner l'eau du vase où cuisaient ces
aignes si savoureuses et si douces, le cœur nous palpitait
joie."—(Ib. p. 9.) "Quand j'arrivais chez moi, et que,
s un bon lit ou au coin d'un bon feu, je me sentais tout
mé, c'était pour moi l'un des moments les plus délicieux
a vie; jouissance que la mollesse ne m'aurait jamais fait
aître."—*(Ib. p. 34.)*

of our senses to receive pleasure, and the supply of external objects fitted to excite it." I allege these as *two* felicities, for they are different things, yet both necessary: the sense being formed, the objects, which were applied to it, might not have suited it; the objects being fixed, the sense might not have agreed with them. A coincidence is here required, which no accident can account for. There are three possible suppositions upon the subject, and no more. The first; that the sense, by its original constitution, was made to suit the object: The second; that the object, by its original constitution, was made to suit the sense: The third; that the sense is so constituted, as to be able, either universally, or within certain limits, by habit and familiarity, to render every object pleasant. Whichever of these suppositions we adopt, the effect evinces, on the part of the Author of nature, a studious benevolence. If the pleasures which we derive from any of our senses depend upon an original congruity between the sense and the properties perceived by it, we know by experience that the adjustment demanded, with respect to the qualities which were conferred upon the objects that surround us, not only choice and selection, out of a boundless variety of possible qualities with which these objects might have been endued, but a *proportioning also of degree*, because an excess or defect of intensity spoils the perception, as much almost as an error in the kind and nature of the quality. Likewise the degree of dulness or acuteness in the sense itself is no arbitrary thing, but, in order to preserve the congruity here spoken of, requires to be in an exact or near correspondency with the strength of the impression. The dulness of the senses forms the complaint of old age. Persons in fevers, and, I believe, in most maniacal cases, experience great torment from their preternatural acuteness. An increased, no less than an impaired sensibility, induces a state of disease and suffering.

The doctrine of a specific congruity between animal senses and their objects is strongly favoured by what is *observed* of insects in the election of their food. Some f these will feed upon one kind of plant or animal, and pon no other: some caterpillars upon the cabbage alone, ome upon the black currant alone. The species of aterpillar which eats the vine will starve upon the alder: or will that which we find upon fennel touch the roseush. Some insects confine themselves to two or three inds of plants or animals. Some again show so strong a reference as to afford reason to believe that, though ey may be driven by hunger to others, they are led by e pleasure of taste to a few particular plants alone; and l this, as it should seem, independently of habit or mitation.

But should we accept the third hypothesis, and even urry it so far as to ascribe every thing which concerns e question to habit (as in certain species, the human ecies most particularly, there is reason to attribute mething), we have then before us an animal capacity, ot less perhaps to be admired than the native congruities hich the other scheme adopts. It cannot be shown to sult from any fixed necessity in nature, that what is equently applied to the senses should of course become greeable to them. It is, so far as it subsists, a power of ccommodation provided in these senses by the Author f their structure, and forms a part of their perfection.

In whichever way we regard the senses, they appear o be specific gifts, ministering, not only to preservation, ut to pleasure. But what we usually call the *senses* re probably themselves far from being the only vehicles f enjoyment, or the whole of our constitution which is alculated for the same purpose. We have many inernal sensations of the most agreeable kind, hardly reerable to any of the five senses. Some physiologists ave holden that all secretion is pleasurable; and that he complacency which in health, without any external ssignable object to excite it, we derive from life itself, is he effect of our secretions going on well within us. All his may be true; but if true, what reason can be asigned for it, except the will of the Creator? It may easonably be asked, Why is any thing a pleasure? and I know no answer which can be returned *to the question* but that which refers it to appointment.

We can give no account whatever of our pleasures in the simple and original perception; and, even when physical sensations are assumed, we can seldom account for them in the secondary and complicated *shapes* in which they take the name of diversions. I never yet met with a sportsman who could tell me in what the sport consisted; who could resolve it into its principle, and state that principle. I have been a great follower of fishing myself, and in its cheerful solitude have passed some of the happiest hours of a sufficiently happy life; but, to this moment, I could never trace out the source of the pleasure which it afforded me.

The "quantum in rebus inane!" whether applied to our amusements or to our graver pursuits (to which, in truth, it sometimes equally belongs), is always an unjust complaint. If trifles engage, and if trifles make us happy, the true reflection suggested by the experiment is upon the tendency of nature to gratification and enjoyment; which is, in other words, the goodness of its Author towards his sensitive creation.

Rational natures also, as such, exhibit qualities which help to confirm the truth of our position. The degree of understanding found in mankind is usually much greater than what is necessary for mere preservation. The pleasure of choosing for themselves, and of prosecuting the object of their choice, should seem to be an original source of enjoyment. The pleasures received from things great, beautiful, or new, from imitation, or from the liberal arts, are, in some measure, not only superadded, but unmixed, gratifications, having no pains to balance them.*

I do not know whether our attachment to *property* be not something more than the mere dictate of reason, or even than the mere effect of association. Property communicates a charm to whatever is the object of it. It is the first of our abstract ideas; it cleaves to us the closest nd the longest. It endears to the child its plaything, o the peasant his cottage, to the landholder his estate. t supplies the place of prospect and scenery. Instead f coveting the beauty of distant situations, it teaches very man to find it in his own. It gives boldness and randeur to plains and fens, tinge and colouring to clays nd fallows.

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* Balguy on the Divine Benevolence

All these considerations come in aid of our *second* proosition. The reader will now bear in mind what our wo propositions were. They were, firstly, that in a ast plurality of instances, in which contrivance is perceived, the design of the contrivance is beneficial; secondly, that the Deity has added pleasure to animal ensations beyond what was necessary for any other purpose: or when the purpose, so far as it was necessary, ight have been effected by the operation of pain.

Whilst these propositions can be maintained, we are uthorised to ascribe to the Deity the character of benevolence; and what is benevolence at all, must in him be *finite* benevolence, by reason of the infinite, that is to y, the incalculably great, number of objects upon which is exercised.

Of the ORIGIN OF EVIL no universal solution has been scovered; I mean, no solution which reaches to all ses of complaint. The most comprehensive is that hich arises from the consideration of *general rules*.[71]

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[71] These observations on General Laws, and those which llow upon the doctrine of Imperfections, have been misderstood in the same way with the former remarks, rerred to in the second note upon this chapter; but it must allowed that the expressions here used respecting General ws are somewhat incautious, and more liable to cavil. evertheless, the whole scope of the argument which follows ainly shows that our author never thought of solving the fficulty as to evil by resorting to the existence of laws, hich are themselves only the modes of acting pursued by e Deity himself. In truth this portion of his argument is, e that on which we formerly commented, only to be conlered *as stating a deduction* to be made from the total *ount of evil; in other* words, the reasoning is only a re-

We may, I think, without much difficulty, be brought to admit the four following points: first, that important advantages may accrue to the universe from the order of nature proceeding according to general laws: secondly, that general laws, however well set and constituted, often thwart and cross one another: thirdly, that from these thwartings and crossings, frequent particular inconveniences will arise: and, fourthly, that it agrees with our observation to suppose, that some degree of these inconveniences takes place in the works of nature. These points may be allowed; and it may also be asserted, that the general laws with which we are acquainted are directed to beneficial ends. On the other hand, with many of these laws we are not acquainted at all, or we are totally unable to trace them in their branches, and in their operation; the effect of which ignorance is, that they cannot be of importance to us as measures by which to regulate our conduct. The conservation of them may be of importance in other respects, or to other beings, but we are uninformed of their value or use; uninformed consequently, when, and how far, they may or may not be suspended, or their effects turned aside, by a presiding and benevolent will, without incurring greater evils than those which would be avoided. The consideration, therefore, of general laws, although it may concern the question of the origin of evil very nearly (which I think it does), rests in views disproportionate to our faculties, and in a knowledge which we do not possess. It serves rather to account for the obscurity of the subject, than to supply us with distinct answers to our difficulties. However, whilst we assent to the above stated propositions, as principles, whatever uncertainty we may find in the application, we lay a ground for believing, that cases of apparent evil, for which *we* can suggest no particular reason, are governed by reasons, which are more general, which lie deeper in

duction of the apparent quantity to the real. Anything beyond this would really be recurring to the ancient doctrine *of the heathens*, whose gods were limited in power and *controlled by fate*.

ɔrder of second causes, and which on that account emoved to a greater distance from us.

ıe doctrine of *imperfections*, or, as it is called, or of imperfection, furnishes an account, founded, like ormer, in views of universal nature. The doctrine iefly this:—It is probable, that creation may be r replenished by sensitive beings of different sorts, by sensitive beings all of one sort. It is likewise ıble, that it may be better replenished by different s of beings rising one above another in gradation, by beings possessed of equal degrees of perfection. , a gradation of such beings implies a gradation of rfections. No class can justly complain of the imctions which belong to its place in the scale, unless re allowable for it to complain, that a scale of being appointed in nature; for which appointment there ar to be reasons of wisdom and goodness.

like manner *finiteness*, or what is resolvable into ness, in inanimate subjects, can never be a just subof complaint; because if it were ever so, it would lways so: we mean, that we can never reasonably nd that things should be larger or more, when the demand might be made, whatever the quantity or ɔer was.

ıd to me it seems that the sense of mankind has so cquiesced in these reasons, as that we seldom comof evils of this class, when we clearly perceive to be such. What I have to add, therefore, is, we ought not to complain of some other evils, which upon the same foot of vindication as evils of cond imperfection. We never complain, that the globe r earth is too small: nor should we complain, if it even much smaller. But where is the difference to etween a less globe, and part of the present being ıabitable? The inhabitants of an island may be apt gh to murmur at the sterility of some parts of it, ıst its rocks, or sands, or swamps: but no one s himself authorised to murmur, simply because the l is not larger than it is. Yet these are the same s, The above are the two metaphysical answers have been given to this great question. They ar the worse for being metaphysical, provided the founded (which I think they are) in right reaso but they are of a nature too wide to be brought und survey, and it is often difficult to apply them i detail. Our speculations, therefore, are perhaps l employed when they confine themselves within a rower circle.

The observations which follow are of this more li but more determinate, kind.

Of *bodily pain*, the principal observation, no do that which we have already made, and already upon, *viz.* "that it is seldom the object of contriv that when it is so, the contrivance rests ultimat good."

To which, however, may be added, that the ann of pain to the means of destruction is a salutar vision; inasmuch as it teaches vigilance and ca both gives notice of danger, and excites those ende which may be necessary to preservation. The evi sequence, which sometimes arises from the want o timely intimation of danger which pain gives, is k to the inhabitants of cold countries by the exam frost-bitten limbs. I have conversed with patient had lost toes and fingers by this cause. They ha general told me, that they were totally unconsci any local uneasiness at the time. Some I have declare, that, whilst they were about their employ neither their situation, nor the state of the air, wa pleasant. They felt no pain; they suspected no chief; till, by the application of warmth, they disco too late the fatal injury which some of their extre had suffered. I say that this shows the use of pair that we stand in need of such a monitor. I believe that the use extends farther than we suppose, or can trace; that to disagreeable sensations we, and all mals, owe, or have owed, many habits of action are salutary, but which are become so familiar a *easily to be* referred to their origin.

[72] PAIN also itself is not without its *alleviations*. may be violent and frequent: but it is seldom both vi lent and long-continued: and its pauses and intermi sions become positive pleasures. It has the power shedding a satisfaction over intervals of ease, which. believe, few enjoyments exceed. A man resting from fit of the stone or gout is, for the time, in possession feelings which undisturbed health cannot impart. The may be dearly bought, but still they are to be set again the price. And, indeed, it depends upon the duratio and urgency of the pain, whether they be dearly boug or not. I am far from being sure, that a man is not gainer by suffering a moderate interruption of bodily eas for a couple of hours out of the four and twenty. Tw very common observations favour this opinion: one is, tha remissions of pain call forth, from those who experienc them, stronger expressions of satisfaction and of gratitud towards both the author and the instruments of thei relief, than are excited by advantages of any other kind the second is, that the spirits of sick men do not sink i proportion to the acuteness of their sufferings; but rathe appear to be roused and supported, not by pain, but b the high degree of comfort which they derive from it cessation, or even its subsidency, whenever that occurs and which they taste with a relish that diffuses som portion of mental complacency over the whole of tha mixed state of sensations in which disease has place them.

In connexion with bodily pain may be considere bodily *disease*, whether painful or not. Few disease are fatal. I have before me the account of a dispensar in the neighbourhood, which states six years' experience as follows :—

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[72] This chapter, we are told by Dr. Fenwick, in his sketc of Dr. Clark's life, "was written when Dr. Paley was su fering under severe attacks of a painful disorder under whic he had long laboured, and which afterwards proved fatal.' Dr. Fenwick justly remarks upon the additional interes which this circumstance communicates to the au marks upon the interruptions of pain.—Meadl of Paley, p. 204.

Admitted	6,420
Cured	5,476
Dead	234

And this I suppose nearly to agree with what other similar institutions exhibit. Now, in all these cases, some disorder must have been felt, or the patients would not have applied for a remedy; yet we see how large a proportion of the maladies which were brought forward have either yielded to proper treatment, or, what is more probable, ceased of their own accord. We owe these frequent recoveries, and, where recovery does not take place, this patience of the human constitution under many of the distempers by which it is visited, to two benefactions of our nature. One is, that she works within certain limits; allows of a certain latitude within which health may be preserved, and within the confines of which it only suffers a graduated diminution. Different quantities of food, different degrees of exercise, different portions of sleep, different states of the atmosphere, are compatible with the possession of health. So likewise it is with the secretions and excretions, with many internal functions of the body, and with the state, probably, of most of its internal organs. They may vary considerably, not only without destroying life, but without occasioning any high degree of inconveniency. The other property of our nature, to which we are still more beholden, is its constant endeavour to restore itself, when disordered, to its regular course. The fluids of the body appear to possess a power of separating and expelling any noxious substance which may have mixed itself with them. This they do, in eruptive fevers, by a kind of despumation, as Sydenham calls it, analogous in some measure to the intestine action by which fermenting liquors work the yest to the surface. The solids, on their part, when their action is obstructed, not only resume that action as soon as the obstruction is removed, but they struggle with the impediment. They take an action as near to the true one, as the difficulty and the disorganisation with which they have to contend will allow of.

Of *mortal* diseases, the great use is to reconcile us to death. The horror of death proves the value of life. But it is in the power of disease to abate, or even extinguish, this horror, which it does in a wonderful manner, and oftentimes by a mild and imperceptible gradation. Every man who has been placed in a situation to observe it, is surprised with the change which has been wrought in himself, when he compares the view which he entertains of death upon a sick-bed, with the heart-sinking dismay with which he should some time ago have met it in health. There is no similitude between the sensations of a man led to execution, and the calm expiring of a patient at the close of his disease. Death to him is only the last of a long train of changes, in his progress through which it is possible that he may experience no shocks or sudden transitions.

Death itself, as a mode of removal and of succession, is so connected with the whole order of our animal world, that almost everything in that world must be changed, to be able to do without it. It may seem likewise impossible to separate the fear of death from the enjoyment of life, or the perception of that fear from rational natures. Brutes are in a great measure delivered from all anxiety on this account by the inferiority of their faculties; or rather they seem to be armed with the apprehension of death just sufficiently to put them upon the means of preservation, and no farther. But would a human being wish to purchase this immunity at the expense of those mental powers which enable him to look forward to the future?

Death implies *separation;* and the loss of those whom we love must necessarily, so far as we can conceive, be accompanied with pain. To the brute creation, nature seems to have stepped in with some secret provi
their relief, under the rupture of their attachm
their *instincts towards their* offspring, and o

ng to them, I have often been surprised to observe ardently they love, and how soon they forget. pertinacity of human sorrow (upon which time also, ength, lays its softening hand) is probably, therefore, ome manner connected with the qualities of our nal or moral nature. One thing, however, is clear, that it is better that we should possess affections, the ces of so many virtues and so many joys, although be exposed to the incidents of life, as well as the rruptions of mortality, than, by the want of them, be ced to a state of selfishness, apathy, and quietism."

f other external evils (still confining ourselves to t are called physical or natural evils), a considerable come within the scope of the following observa- :—The great principle of human satisfaction is en- *ement.* It is a most just distinction, which the late Tucker has dwelt upon so largely in his works, be- en pleasures in which we are passive, and pleasures hich we are active. And I believe every attentive rver of human life will assent to his position, that, ever grateful the sensations may occasionally be in ch we are passive, it is not these, but the latter class our pleasures which constitute satisfaction, which ly that regular stream of moderate and miscellaneous yments in which happiness, as distinguished from ptuousness, consists. Now for rational occupation, ch is, in other words, for the very material of con- ed existence, there would be no place left, if either things with which we had to do were absolutely in- ticable to our endeavours, or if they were too obedient ur uses. A world furnished with advantages on one , and beset with difficulties, wants, and inconveni- s on the other, is the proper abode of free, rational, active natures, being the fittest to stimulate and ex- se their faculties. The very *refractoriness* of the cts they have to deal with contributes to this pur- . A world in which nothing depended upon our- es, however it might have suited an imaginary race of

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The remarks made in note 71 are applicable to this *of the text also.*

, would not have suited mankind. Their skill, ence, industry,—their various arts and their best ments, from the application of which they draw, if their highest, their most permanent gratifications, d be insignificant, if things could be either moulded ur volitions, or, of their own accord, conformed selves to our views and wishes. Now it is in this ctoriness that we discern the seed and principle of *ical* evil, as far as it arises from that which is exter- o us.

vil evils,[74] or the evils of civil life, are much more disposed of than physical evils, because they are th of much less magnitude, and also because they t, by a kind of necessity, not only from the constitu- of our nature, but from a part of that constitution h no one would wish to see altered. The case is Mankind will in every country *breed up* to a cer- point of distress. That point may be different in ent countries or ages, according to the established s of life in each. It will also shift upon the scale, o admit of a greater or less number of inhabitants, ing as the quantity of provision, which is either ed in the country or supplied to it from other es, may happen to vary. But there must always a point, and the species will always breed up to e order of generation proceeds by something like trical progression. The increase of provision, rcumstances even the most advantageous, can me the form of an arithmetic series. Whence that the population will always overtake the will pass beyond the line of plenty, and will

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arguments respecting civil and political evils it t to keep the distinction steadily in view between t under necessary sufferings, and quietism under be avoided by improvements in our institutions. t, indeed, under even the latter, is a virtue as ce during the period required for their safe and nendment; but this is no exception to the rule e glanced at, for the sufferings must be consi- y until their removal can be safely effected.

continue to increase till checked by the difficulty of procuring subsistence.* Such difficulty, therefore, along with its attendant circumstances, *must* be found in every old country; and these circumstances constitute what we call poverty, which necessarily imposes labour, servitude, restraint.

It seems impossible to people a country with inhabitants who shall be all easy in circumstances. For suppose the thing to be done, there would be such marrying and giving in marriage amongst them, as would in a few years change the face of affairs entirely, *i. e.* as would increase the consumption of those articles which supplied the natural or habitual wants of the country to such a degree of scarcity, as must leave the greatest part of the inhabitants unable to procure them without toilsome endeavours, or out of the different kinds of these articles to procure any kind except that which was most easily produced. And this in fact describes the condition of the mass of the community in all countries, a condition unavoidably, as it should seem, resulting from the provision which is made in the human, in common with all animal constitutions, for the perpetuity and multiplication of the species.

It need not, however, dishearten any endeavours for the public service, to know that population naturally treads upon the heels of improvement. If the condition of a people be meliorated, the consequence will be either that the *mean* happiness will be increased, or a greater number partake of it; or, which is most likely to happen, that both effects will take place together. There may be limits fixed by nature to both, but they are limits not yet attained nor even approached in any country of the world.

And when we speak of limits at all, we have respect only to provisions for animal wants. There are sources and means, and auxiliaries, and augmentations of human happiness, communicable without restriction of numbers; as capable of being possessed by a thousand persons as by one. Such are those which flow from a mild, contrasted with a tyrannic government, whether civil or domestic; those which spring from religion; those which grow out of a sense of security; those which depend upon habits of virtue, sobriety, moderation, order; those, lastly, which are found in the possession of well-directed tastes and desires, compared with the dominion of tormenting, pernicious, contradictory, unsatisfied, and unsatisfiable passions.

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* See a statement of this subject in a late treatise upon *population.—Note of the Author.*

The *distinctions* of civil life are apt enough to be regarded as evils by those who sit under them; but, in my opinion, with very little reason.

In the first place, the advantages which the higher conditions of life are supposed to confer bear no proportion in value to the advantages which are bestowed by nature. The gifts of nature always surpass the gifts of fortune. How much, for example, is activity better than attendance; beauty than dress; appetite, digestion, and tranquil bowels, than all the studies of cookery, or than the most costly compilation of forced or far-fetched dainties!

Nature has a strong tendency to equalisation. Habit, the instrument of nature, is a great leveller; the familiarity which it induces taking off the edge both of our pleasures and our sufferings. Indulgences which are habitual, keep us in ease, and cannot be carried much farther. So that with respect to the gratifications of which the senses are capable, the difference is by no means proportionable to the apparatus. Nay, so far as superfluity generates fastidiousness, the difference is on the wrong side.

It is not necessary to contend, that the advantages derived from wealth are none (under due regulations they are certainly considerable), but that they are not greater than they ought to be. *Money* is the sweetener of human toil; the substitute for coercion; the reconciler of labour with *liberty*. *It* is, moreover, the stimul enterprise in all projects and undertakings, as of diligence in the most beneficial arts and emplo Now, did affluence, when possessed, contribute to happiness, or nothing beyond the mere supply of necessaries,—and the secret should come to be discovered,—we might be in danger of losing great part of the uses which are at present derived to us through this important medium. Not only would the tranquillity of social life be put in peril by the want of a motive to attach men to their private concerns; but the satisfaction which all men receive from success in their respective occupations, which collectively constitutes the great mass of human comfort, would be done away in its very principle.

With respect to *station*, as it is distinguished from riches, whether it confer authority over others, or be invested with honours which apply solely to sentiment and imagination, the truth is that what is gained by rising through the ranks of life is not more than sufficient to draw forth the exertions of those who are engaged in the pursuits which lead to advancement, and which, in general, are such as ought to be encouraged. Distinctions of this sort are subjects much more of competition than of enjoyment; and in that competition their use consists. It is not, as hath been rightly observed, by what the *Lord Mayor* feels in his coach, but by what the *apprentice* feels who gazes at him, that the public is served.

As we approach the summits of human greatness, the comparison of good and evil, with respect to personal comfort, becomes still more problematical; even allowing to ambition all its pleasures. The poet asks, "What is grandeur, what is power?" The philosopher answers, "Constraint and plague: *et in maximâ quâque fortunâ minimum licere.*" One very common error misleads the opinion of mankind on this head, *viz.* that, universally, authority is pleasant, submission painful. In the general course of human affairs, the very reverse of this is nearer the truth. Command is anxiety, obedience ease.

Artificial distinctions sometimes promote real equality. Whether they be hereditary, or be the homage paid to
r the respect attached by public opinion to par-
rofessi re to *confront* that grandeur,
le h arises from property, an

most overbearing where there is no other. It nature of property, not only to be irregularly ›d, but to run into large masses. Public laws ; so constructed as to favour its diffusion as much an. But all that can be done by laws, consist- h that degree of government of his property ight to be left to the subject, will not be suffi- ›ounteract this tendency. There must always, , be the difference between rich and poor; and rence will be the more grinding when no pre- s allowed to be set up against it.

t the evils, if evils they must be called, which ther from the necessary subordinations of civil om the distinctions which have naturally, though ssarily, grown up in most societies, so long as unaccompanied by privileges injurious or op- to the rest of the community, are such as may, the most depressed ranks, be endured with very judice to their comfort.

ischiefs of which mankind are the occasion to her, by their private wickednesses and cruelties; nical exercises of power; by rebellions against ority; by wars; by national jealousies and com- operating to the destruction of third countries; ıer instances of misconduct either in individuals ies, are all to be resolved into the character of *free agent.* Free agency, in its very essence, liability to abuse. Yet, if you deprive man o agency, you subvert his nature. You may have ›m him and regularity, as you may from the tides ade-winds, but you put an end to his moral cha- › virtue, to merit, to accountableness, to the use f reason. To which must be added the observa- ıt even the bad qualities of mankind have an ı their good ones. The case is this: Human are either necessary to human welfare, or ca- being made, and, in a great majority of in- in fact made, conducive to its happiness. These are strong and general; and, perhaps, would wer their *purpose* unless they were so. But strength and generality, when it is expedient that particular circumstances should be respected, become, if le to themselves, excess and misdirection. From whic excess and misdirection, the vices of mankind (t causes, no doubt, of much misery) appear to spri This account, whilst it shows us the principle of vic shows us, at the same time, the province of reason an of self-government; the want also of every suppo which can be procured to either from the aids of religion; and it shows this, without having recourse to any native, gratuitous malignity in the human constitution. Mr. Hume, in his posthumous dialogues, asserts, indeed, of *idleness*, or aversion to labour (which he states to lie at the root of a considerable part of the evils which mankind suffer), that it is simply and merely bad. But how does he distinguish idleness from the love of ease? or is he sure, that the love of ease in individuals is not the chief foundation of social tranquillity? It will be found, I believe, to be true, that in every community there is a large class of its members, whose idleness is the best quality about them, being the corrective of other bad ones. If it were possible, in every instance, to give a right determination to industry, we could never have too much of it. But this is not possible, if men are to be free. And without this, nothing would be so dangerous, as an incessant, universal, indefatigable activity. In the civil world, as well as in the material, it is the *vis inertiæ* which keeps things in their places.

NATURAL THEOLOGY has ever been pressed with this question. Why, under the regency of a supreme and benevolent Will, should there be in the world so much as there is of the appearance of *chance*?

The question in its whole compass lies beyond our reach; but there are not wanting, as in the origin of evil, answers which seem to have considerable w particular cases, and also to embrace a considerabl [illegible]

There must be chance in the midst of de we mean, that events which are not necessarily arise from the pursuit of events which are designed. One man travelling to York, meets another man travelling to London. Their meeting is by chance, is accidental, and so would be called and reckoned, though the journeys which produced the meeting were, both of them, undertaken with design and from deliberation. The meeting, though accidental, was nevertheless hypothetically necessary (which is the only sort of necessity that is intelligible): for if the two journeys were commenced at the time, pursued in the direction, and with the speed, in which and with which they were in fact begun and performed, the meeting could not be avoided. There was not, therefore, the less necessity in it for its being by chance. Again, the rencounter might be most unfortunate, though the errand, upon which each party set out upon his journey, were the most innocent or the most laudable. The by-effect may be unfavourable, without impeachment of the proper purpose, for the sake of which the train, from the operation of which these consequences ensued, was put in motion. Although no cause act without a good purpose, accidental consequences, like these, may be either good or bad.

II. The *appearance of chance* will always bear a proportion to the ignorance of the observer. The cast of a die as regularly follows the laws of motion, as the going of a watch; yet, because we can trace the operation of those laws through the works and movements of the watch, and cannot trace them in the shaking or throwing of the die (though the laws be the same, and prevail equally in both cases), we call the turning up of the number of the die, chance; the pointing of the index of the watch, machinery, order, or by some name which excludes chance. It is the same in those events which depend upon the will of a free and rational agent. The verdict of a jury, the sentence of a judge, the resolution of an assembly, the issue of a contested election, will have more or less the appearance of chance, might be more or less the subject of a wager, according as we were less or *more* acquainted with the reasons which influenced the deliberation. The difference resides in the information of the observer, and not in the thing itself; which, in all the cases proposed, proceeds from intelligence, from mind, from counsel, from design.[75]

Now when this one cause of the appearance of chance, *viz*. the ignorance of the observer, comes to be applied to the operations of the Deity, it is easy to foresee how fruitful it must prove of difficulties and of seeming confusion. It is only to think of the Deity, to perceive what variety of objects, what distance of time, what extent of space and action, his counsels may, or rather must, comprehend. Can it be wondered at, that, of the purposes which dwell in such a mind as this, so small a part should be known to us? It is only necessary, therefore, to bear in our thought, that in proportion to the inadequateness of our information, will be the quantity in the world of apparent chance.

III. In a great variety of cases, and of cases comprehending numerous subdivisions, it appears, for many reasons, to be better that events rise up by *chance*, or, more properly speaking, with the appearance of chance, than according to any observable rule whatever. This is not seldom the case even in human arrangements. Each person's place and precedency, in a public meeting, may be determined by *lot*. Work and labour may be *allotted*. Tasks and burdens may be *allotted:*

> ——— Operumque laborem
> Partibus æquabat justis, aut *sorte* trahebat.

Military service and station may be *allotted*. The distribution of provision may be made by *lot*, as it is in a sailor's mess; in some cases also, the distribution of favours may be made by *lot*. In all these cases, it seems to be acknowledged, that there are advantages in permitting events to chance superior to those which would or could arise from regulation. In all these cases also, though events rise up in the way of chance, it is by appointment that they do so.

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[75] See note to p. 55 of vol. ii. respecting Chance. This paragraph is wholly free from the inaccuracy taken notice of in the former note.

In other events, and such as are independent of human will, the reasons for this preference of uncertainty to rule appear to be still stronger. For example: it seems to be expedient that the period of human life should be *uncertain*. Did mortality follow any fixed rule, it would produce a security in those that were at a distance from it, which would lead to the greatest disorders; and a horror in those who approached it, similar to that which a condemned prisoner feels on the night before his execution. But, that death be uncertain, the young must sometimes die, as well as the old. Also were deaths never *sudden*, they who are in health would be too confident of life. The strong and the active, who want most to be warned and checked, would live without apprehension or restraint. On the other hand, were sudden deaths very frequent, the sense of constant jeopardy would interfere too much with the degree of ease and enjoyment intended for us; and human life be too precarious for the business and interests which belong to it. There could not be dependence either upon our own lives, or the lives of those with whom we were connected, sufficient to carry on the regular offices of human society. The manner, therefore, in which death is made to occur, conduces to the purposes of admonition, without overthrowing the necessary stability of human affairs.[76]

Disease being the forerunner of death, there is the same reason for its attacks coming upon us under the appearance of chance, as there is for uncertainty in the time of death itself.

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[76] It must never be forgotten that, according to the scheme, whether of Natural or of Revealed Religion, the doctrine of a Future State removes one branch of the evil here treated of, and answers the common sceptical objection grounded upon the destruction of one being made the means of benefit to another. In the view of religion, the person removed by Providence is to be considered as suffering no loss whatever,—he is at once taken to a superior state. The survivors alone are to be considered as regards the question of evil.

The *seasons* are a mixture of regularity and chance. They are regular enough to authorise expectation, whilst their being in a considerable degree irregular induces, on the part of the cultivators of the soil, a necessity for personal attendance, for activity, vigilance, precaution. It is this necessity which creates farmers; which divides the profit of the soil between the owner and the occupier; which by requiring expedients, by increasing employment, and by rewarding expenditure, promotes agricultural arts and agricultural life, of all modes of life the best, being the most conducive to health, to virtue, to enjoyment. I believe it to be found, in fact, that where the soil is the most fruitful, and the seasons the most constant, there the condition of the cultivators of the earth is the most depressed. Uncertainty, therefore, has its use even to those who sometimes complain of it the most. Seasons of scarcity themselves are not without their advantages.[77] They call forth new exertions; they set contrivance and ingenuity at work; they give birth to improvements in agriculture and œconomy; they promote the investigation and management of public resources.

Again: there are strong intelligible reasons why there should exist in human society great disparity of wealth and *station;* not only as these things are acquired in different degrees, but at the first setting out of life. In order, for instance, to answer the various demands of civil life, there ought to be amongst the members of every civil society a diversity of education, which can only belong to an original diversity of circumstances. As this sort of disparity, which ought to take place from the beginning of life, must, *ex hypothesi*, be previous to the merit or demerit of the persons upon whom it falls, can it be better disposed of than by chance? *Parentage* is that sort of chance: yet it is the commanding circum-

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[77] See former note upon the only legitimate application of *such arguments*.

general fixes each man's place in civil
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ay be the result of a beneficial rule, that
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should seem, of a still more necessary
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be done.

be also true, that the exigencies of social
for an original diversity of *external* cir-
for a mixture of different faculties, tastes,
Activity and contemplation, restlessness
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y even indolence and dulness, are all
orld, all conduce to the well going on of
st as the rudder, the sails, and the bal-
ll perform their part in the navigation.
e characters require for their foundation

different original talents, different dispositions, perhaps also different bodily constitutions; and since, likewise, it is apparently expedient, that they be promiscuously scattered amongst the different classes of society,—can the distribution of talents, dispositions, and the constitutions upon which they depend, be better made than by *chance?*

The *opposites* of apparent chance are constancy and sensible interposition; every degree of *secret* direction being consistent with it. Now of *constancy*, or of fixed and known rules, we have seen in some cases the inapplicability; and inconveniences which we do not see, might attend their application in other cases.

Of *sensible* interposition, we may be permitted to remark, that a Providence, always and certainly distinguishable, would be neither more nor less than miracles rendered frequent and common. It is difficult to judge of the state into which this would throw us. It is enough to say, that it would cast us upon a quite different dispensation from that under which we live. It would be a total and radical change. And the change would deeply affect, or perhaps subvert, the whole conduct of human affairs. I can readily believe, that, other circumstances being adapted to it, such a state might be better than our present state. It may be the state of other beings; it may be ours hereafter. But the question with which we are now concerned is, how far it would be consistent with our condition, supposing it in other respects to remain as it is? And in this question there seem to be reasons of great moment on the negative side. For instance: so long as bodily labour continues, on so many accounts, to be necessary for the bulk of mankind, any dependency upon supernatural aid, by unfixing those motives which promote exertion, or by relaxing those habits which engender patient industry, might introduce negligence, inactivity, and disorder, into the most useful occupations of human life; and thereby deteriorate the condition of human life itself.

As moral agents we should experience a still greater

teration; of which more will be said under the next
ticle.

Although, therefore, the Deity, who possesses the
wer of winding and turning, as he pleases, the course
causes which issue from himself, do in fact interpose
alter or intercept effects which, without such inter-
sition, would have taken place; yet it is by no means
credible that his Providence, which always rests upon
al good, may have made a *reserve* with respect to the
anifestation of his interference, a part of the very plan
hich he has appointed for our terrestrial existence, and
part conformable with, or in some sort required by,
her parts of the same plan. It is at any rate evident,
at a large and ample province remains for the exercise
Providence without its being naturally perceptible by
; because obscurity, when applied to the interruption
laws, bears a necessary proportion to the imperfection
our knowledge when applied to the laws themselves,
rather to the effects which these laws, under their
rious and incalculable combinations, would of their own
cord produce. And if it be said, that the doctrine of
ivine Providence, by reason of the ambiguity under
hich its exertions present themselves, can be attended
ith no *practical* influence upon our conduct; that, al-
ough we believe ever so firmly that there is a Pro-
dence, we must prepare, and provide, and act, as if
ere were none; I answer, that this is admitted; and
at we further allege, that so to prepare, and so to pro-
de, is consistent with the most perfect assurance of the
ality of a Providence: and not only so, but that it is,
obably, one advantage of the present state of our in-
rmation, that our provisions and preparations are not
sturbed by it. Or if it be still asked, Of what use at
l, then, is the doctrine, if it neither alter our measures
r regulate our conduct? I answer again, that it is of
e greatest use, but that it is a doctrine of sentiment and
ety, not (immediately at least) of action or conduct;
at it applies to the consolation of men's minds, to their
votions, to the excitement of gratitude, the support of
tience, *the keeping alive* and the strengthening of

every motive for endeavouring to please our Ma
that these are great uses.[78]

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[78] The views taken in these three paragraphs
important, and they lead to another of equal mo
indeed, they do not include it), respecting the
which hangs over the subject of a Future State.
have constantly asked,—Why a matter, beyond all
son the most important and the most interesting
should be left in any the least doubt? in other wo
the combined operation of Natural and Revealed
should not be to make us just as certain of what sh
us upon our removal from this world as we are o
likely to happen on the morrow of any given da
answer is,—*because* this matter is so immeasura
important and more interesting to us than all oth
because, unless our whole nature were changed, the
certainty of enjoyments without end and with
would make the performance of our present task in
If, indeed, the further question is pressed,—" Wh
so constituted?"—this is only another form of wha
all these reasonings conceal, the question, Why
created a finite being? For in this all the sceptical
of the description adverted to invariably end. Thu
an instance from one gratification which of neces
supposes evil,—There is pleasure in the cessation
and in the enjoyment of rest after labour; as there
satisfying the thirst for knowledge. It is not a c
but a necessary truth, that this gratification of ea
curiosity satisfied, cannot be obtained without the p
evil of suffering or fatigue, or the preceding imper
ignorance. But it is said, why might we not hav
made as to have other equal pleasures without t
And had such been our constitution, the same
would have said,—" Here is one source of enjoy
off." Nay, if life were an alternation of positive en
with mere ease, they would still say,—" Why any
of positive enjoyment, compared with which mer
worthless, and so an evil?" And if all were positi
ment, they would say,—" Why is it not more ex
in other words,—" Why is man a finite being?"
speculations, however, upon this subject must proce
the assumption that the design of Providence was

Of all views under which human life has ever been considered, the most reasonable, in my judgment, is that which regards it as a state of *probation*. If the course of the world was separated from the contrivances of nature, I do not know that it would be necessary to look for any other account of it than what, if it may be called an account, is contained in the answer, that events rise up by chance. But since the contrivances of nature decidedly evince *intention;* and since the course of the world and the contrivances of nature have the same author; we are, by the force of this connexion, led to believe that the appearance under which events take place, is reconcileable with the supposition of design on the part of the Deity. It is enough that they be reconcileable with this supposition; and it is undoubtedly true that they may be reconcileable, though we cannot reconcile them. The mind, however, which contemplates the works of nature, and in those works sees so much of means directed to ends, of beneficial effects brought about by wise expedients, of concerted trains of causes terminating in the happiest results; so much, in a word, of counsel, intention, and benevolence; a mind, I say, drawn into the habit of thought which these observations excite, can hardly turn its view to the condition of our own species without endeavouring to suggest to itself some purpose, some design, for which the state in which we are placed is fitted, and which it is made to serve. Now we assert the most probable supposition to be, that it is a state of moral probation; and that many things in

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a finite, mortal creature, endowed with free will, but influenced by motives inducing and dissuading. Any inquiry into the reason for such a determination being taken by the Supreme Being far exceeds the bounds of our faculties; and the question as to evil must be always handled with the impression that, beyond a certain way, we never can make progress towards its entire solution. The whole subject, with the different doctrines held upon it, will be treated at large in the Appendix, where it will be contended that the most enlarged views lead to the conclusion of rational optimism and a probationary state.

it suit with this hypothesis which suit no other. It is not a state of unmixed happiness, or of happiness simply; it is not a state of designed misery, or of misery simply: it is not a state of retribution; it is not a state of punishment. It suits with none of these suppositions. It accords much better with the idea of its being a condition calculated for the production, exercise, and improvement of moral qualities, with a view to a future state, in which these qualities, after being so produced, exercised, and improved, may, by a new and more favourable constitution of things, receive their reward, or become their own. If it be said, that this is to enter upon a religious rather than a philosophical consideration, I answer, that the name of Religion ought to form no objection if it shall turn out to be the case that the more religious our views are the more probability they contain. The degree of beneficence, of benevolent intention, and of power, exercised in the construction of sensitive beings, goes strongly in favour, not only of a creative, but of a continuing care, that is, of a ruling Providence. The degree of chance which appears to prevail in the world requires to be reconciled with this hypothesis. Now it is one thing to maintain the doctrine of Providence along with that of a future state, and another thing without it. In my opinion, the two doctrines must stand or fall together. For although more of this apparent chance may perhaps, upon other principles, be accounted for than is generally supposed, yet a future state alone rectifies all disorders: and if it can be shown that the appearance of disorder is consistent with the uses of life as a *preparatory* state, or that in some respects it promotes these uses, then, so far as this hypothesis may be accepted, the ground of the difficulty is done away.

In the wide scale of human condition there is not, perhaps, one of its manifold diversities which does not bear upon the design here suggested. Virtue is infinitely
ious. There is no situation in which a rational being
aced, from that of the best-instructed Christian down
e condition of the rudest barbarian, which affords
om for moral agency,—for the acquisition, exercise

and display of voluntary qualities, good and bad. Health and sickness, enjoyment and suffering, riches and poverty, knowledge and ignorance, power and subjection, liberty and bondage, civilization and barbarity, have all their offices and duties, all serve for the *formation* of character: for when we speak of a state of trial, it must be remembered that characters are not only tried, or proved, or detected, but that they are generated also and *formed* by circumstances. The best dispositions may subsist under the most depressed, the most afflicted fortunes. A West Indian slave, who, amidst his wrongs, retains his benevolence, I, for my part, look upon as amongst the foremost of human candidates for the rewards of virtue. The kind master of such a slave, that is, he who, in the exercise of an inordinate authority, postpones in any degree his own interest to his slave's comfort, is likewise a meritorious character, but still he is inferior to his slave. All, however, which I contend for is, that these destinies, opposite as they may be in every other view, are both *trials*, and equally such. The observation may be applied to every other condition, to the whole range of the scale, not excepting even its lowest extremity. *Savages* appear to us all alike; but it is owing to the distance at which we view savage life, that we perceive in it no discrimination of character. I make no doubt but that moral qualities, both good and bad, are called into action as much, and that they subsist in as great variety in these inartificial societies, as they are or do in polished life. Certain at least it is, that the good and ill treatment which each individual meets with depends more upon the choice and voluntary conduct of those about him than it does or ought to do under regular civil institutions and the coercion of public laws. So again, to turn our eyes to the other end of the scale, namely, that part of it which is occupied by mankind enjoying the benefits of learning, together with the lights of revelation; there also the advantage is all along *probationary*. Christianity itself, I mean the revelation of Christianity, is not only a blessing, ut a trial. It is one of the diversified means by which he *character is exercised*; and they who require of

Christianity that the revelation of it should be universal, may possibly be found to require that one species of probation should be adopted, if not to the exclusion of others, at least to the narrowing of that variety which the wisdom of the Deity hath appointed to this part of his moral œconomy.*

Now if this supposition be well founded, that is, if it be true that our ultimate or our most permanent happiness will depend, not upon the temporary condition into which we are cast, but upon our behaviour in it, then is it a much more fit subject of *chance* than we usually allow or apprehend it to be, in what manner the variety of external circumstances which subsist in the human world is distributed amongst the individuals of the species. “This life being a state of probation, it is immaterial,” says Rousseau, “what kind of trials we experience in it, provided they produce their effects.” Of two agents who stand indifferent to the moral Governor of the universe, one may be exercised by riches, the other by poverty. The treatment of these two shall appear to be very opposite, whilst in truth it is the same; for though, in many respects, there be great disparity between the conditions assigned, in one main article there may be none, *viz.* in that they are alike trials, have both their duties and temptations not less arduous or less dangerous in one case than the other: so that if the final award follow the character, the original distribution of the circumstances under which that character is formed may be defended upon principles not only of justice, but of equality. What hinders, therefore, but that mankind

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* The reader will observe that I speak of the revelation of Christianity as distinct from Christianity itself. The *dispensation* may already be universal. That part of mankind which never heard of CHRIST's name, may nevertheless be redeemed, that is, be placed in a better condition, with respect to their future state, by his intervention,—may be the objects of his benignity and intercession, as well as of the propitiatory virtue of his passion. But this is not “natural *theology*,” therefore I will not dwell longer upon it.—*Note of the Author.*

may draw lots for their condition? They take thei
portion of faculties and opportunities, as any unknow
cause, or concourse of causes, or as causes acting fo
other purposes, may happen to set them out; but the event is governed by that which depends upon themselves, the application of what they have received. In dividing the talents, no rule was observed,—none was necessary; in rewarding the use of them, that of the most correct justice. The chief difference at last appears to be, that the right use of more talents, *i. e.* of a greater trust, will be more highly rewarded than the right use of fewer talents, *i. e.* of a less trust. And since for other purposes it is expedient that there be an inequality of concredited talents here, as well probably as an inequality of conditions hereafter, though all remuneratory,—can any rule adapted to that inequality be more agreeable, even to our apprehensions of distributive justice, than this is?

We have said that the appearance of *casualty* which attends the occurrences and events of life not only does not interfere with its uses, as a state of probation, but that it promotes these uses.

Passive virtues, of all others the severest and the most
iblime,—of all others, perhaps, the most acceptable to
ıe Deity,—would, it is evident, be excluded from a
nstitution in which happiness and misery regularly fol-
wed virtue and vice. Patience and composure under
stress, affliction, and pain; a steadfast keeping up of
confidence in God, and of our reliance upon his final
dness, at the time when everything present is adverse
discouraging; and (what is no less difficult to retain)
rdial desire for the happiness of others, even when
are deprived of our own; these dispositions, which
titute, perhaps, the perfection of our moral nature,
'd not have found their proper office and object in a
of avowed retribution, and in which, consequently,
ance of evil would be only submission to punish-

ain, one man's sufferings may be another man's
The *family of a sick* parent is a school of filial

piety. The charities of domestic life, and not only these, but all the social virtues, are called out by distress. But then misery, to be the proper object of mitigation, or of that benevolence which endeavours to relieve, must be really or apparently casual. It is upon such sufferings alone that benevolence can operate. For were there no evils in the world but what were punishments, properly and intelligibly such, benevolence would only stand in the way of justice. Such evils, consistently with the administration of moral government, could not be prevented or alleviated, that is to say, could not be remitted in whole or in part, except by the authority which inflicted them, or by an appellate or superior authority. This consideration, which is founded in our most acknowledged apprehensions of the nature of penal justice, may possess its weight in the Divine counsels. Virtue, perhaps, is the greatest of all ends. In human beings, relative virtues form a large part of the whole. Now relative virtue presupposes, not only the existence of evil—without which it could have no object, no material to work upon—but that evils be apparently, at least, *misfortunes*, that is, the effects of apparent chance. It may be in pursuance, therefore, and in furtherance of the same scheme of probation, that the evils of life are made so to present themselves.

I have already observed that when we let in religious considerations, we often let in light upon the difficulties of nature. So in the fact now to be accounted for; the *degree* of happiness which we usually enjoy in this life may be better suited to a state of trial and probation than a greater degree would be. The truth is, we are rather too much delighted with the world than too little. Imperfect, broken, and precarious as our pleasures are, they are more than sufficient to attach us to the eager pursuit of them. A regard to a *future* state can hardly keep its place as it is. If we were designed, therefore, to be influenced by that regard, might not a more indulgent system, a higher or more uninterrupted state of gratification, have interfered with the design? At least it seems *expedient that* mankind should be susceptible of this in-when presented to them, that the condition of ld should not be such as to exclude its operation, to weaken it more than it does. In a religious owever we may complain of them in every other), n, disappointment, and satiety, are not without it salutary tendencies.

CHAPTER XXVII.

CONCLUSION.

In all cases wherein the mind feels itself in danger being confounded by variety, it is sure to rest upon few strong points, or perhaps upon a single instance. Amongst a multitude of proofs, it is *one* that does business. If we observe in any argument that hard two minds fix upon the same instance, the diversity choice shows the strength of the argument, because shows the number and competition of the exampl There is no subject in which the tendency to dwell u select or single topics is so usual—because there is subject of which, in its full extent, the latitude is great—as that of natural history applied to the proof an intelligent Creator. For my part, I take my st in human anatomy; and the examples of mechanism should be apt to draw out from the copious catalog which it supplies, are the pivot upon which the he turns, the ligaments within the socket of the hip-joint, the pulley or trochlear muscles of the eye, the epiglottis, the bandages which tie down the tendons of the wri and instep, the slit or perforated muscles at the han and feet, the knitting of the intestines to the mesentery, the course of the chyle into the blood, and the constitution of the sexes as extended throughout the whole the animal creation. To these instances the reader's memory will go back, as they are severally set forth in their places: there is not one of the number which I not think decisive; not one which is not strictly mechanical: nor have I read or heard of any solution of these appearances which in the smallest degree shakes the *conclusion* that we build upon them.

t of the greatest part of those who, either in this or any other, read arguments to prove the existence God, it will be said that they leave off only where began; that they were never ignorant of this great , never doubted of it; that it does not therefore ır what is gained by researches from which no new on is learned, and upon the subject of which no s were wanted. Now, I answer that by *investiga-* he following points are always gained in favour of ines even the most generally acknowledged (sup- g them to be true), *viz.* stability and impression. sions will arise to try the firmness of our most habi- pinions. And upon these occasions it is a matter calculable use to feel our foundation, and find a sup- in argument for what we had taken up upon autho-

In the present case the arguments upon which the usion rests are exactly such as a truth of universal rn ought to rest upon. "They are sufficiently open e views and capacities of the unlearned, at the same that they acquire new strength and lustre from the veries of the learned." If they had been altogether use and recondite, they would not have found their to the understandings of the mass of mankind; if had been merely popular, they might have wanted ty.

t, secondly, what is gained by research in the sta- of our conclusion is also gained from it in *impres-* Physicians tell us that there is a great deal of

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We have adverted in a former note (Chap. xxv.) to the ted silence of Laplace upon the inferences to which his important researches so naturally lead. An objection kind in some respects similar, but in others materially ent, has often been urged against another class of rs,—the historians who record, without observation, s in which pious men are prone to trace the interposition ovidence. This charge was brought, upon one remark- occasion, against the narrative of a celebrated voyage scovery; and the author, Dr. Hawkesworth, defended lf in an elaborate and ingenious manner. He urged ither *the event* (*the* ceasing of the wind at a critical difference between taking a medicine and t getting into the constitution, a difference which obtains with respect to those great m tions which ought to form the directing human conduct. It is one thing to assent t tion of this sort; another, and a very differ have properly imbibed its influence. I tak be this: perhaps almost every man living ha train of thought, into which his mind gli when at leisure from the impressions and ide sionally excite it; perhaps also the train of spoken of, more than any other thing, de character. It is of the utmost consequen that this property of our constitution be we

moment, by which Captain Cook's ship, after on a coral rock, was saved, contrary to all exp pened in the ordinary course of nature, and t more to be called providential than the risi upon any given day; or it was produced by an interposition, and then the same power might this unnecessary, by preventing the ship (Voyages, vol. i. p. 21, second edition.) But proceeds upon an entire misapprehension of No one denies that the good and the evil c same Almighty hand; but resting in the bel Dr. Hawkesworth himself in explicit terms, preme Being is equally wise and benevolent i tion of both evil and good as means of eff purposes worthy of his ineffable perfections" may, with the most absolute consistency, ex ness for the one and resigned submission to pensation; and it is a wholesome habit of thi according with our duty to that awful and ben as well as conducive to our own mental i make our gratitude for his bounties keep pac signation to his will. Those, therefore, who pass by an occasion of marking the proofs o and intelligence where it naturally present themselves to blame; and those who, as it w their way to avoid marking instances of his b censurable. Both classes neglect a fit oppo moting human improvement.

nt or continued meditation upon a subject in different points of view, iculars, by variety of examples, by to the solution of phenomena, by and consequences, that mental ex- any particular channel. It is by that we have any power over it. ous thought, and the choice of that l to different ends, and may appear judiciously fixed, according to the f which we consider it; but, in a t, I believe, be contradicted when I of thinking be more desirable than ch regards the phenomena of nature ice to a supreme, intelligent Author. he ruling, the habitual sentiment of laid the foundation of everything The world thenceforth becomes a lf one continued act of adoration. s than this; that, whereas formerly our thoughts, we can now scarcely without perceiving its relation to ed natural body, in the provisions its sustentation and propagation, ne part of the Creator expressly rposes. We are on all sides sur- es; examined in their parts, won- npared with one another, no less l. So that the mind, as well as the itiate in variety and multitude, o investigation of particular division in either case it will rise up from sed by the subject, in a very dif- ith a very different degree of influ- re assent to any verbal proposition l concerning the existence of the erely complying assent with which isfied, and with which we are too es, will or can produce upon the ecially may this difference be perceived in the degree of admiration and of awe with w the Divinity is regarded when represented to the un standing by its own remarks, its own reflections, an own reasonings, compared with what is excited by language that can be used by others. The work nature want only to be contemplated. When con plated, they have everything in them which can asto by their greatness; for, of the vast scale of opera through which our discoveries carry us, at one end see an intelligent Power arranging planetary syst fixing, for instance, the trajectory of *Saturn*, or structing a ring of two hundred thousand miles' diam to surround his body, and be suspended like a magnifi arch over the heads of his inhabitants; and at the o bending a hooked tooth, concerting and providing appropriate mechanism for the clasping and reclaspin the filaments of the feather of the humming-bird. have proof, not only of both these works proceeding f an intelligent agent, but of their proceeding from same agent; for, in the first place, we can trace an i tity of plan, a connexion of system, from Saturn to own globe; and when arrived upon our globe, we in the second place, pursue the connexion through the organised, especially the animated, bodies whic supports. We can observe marks of a common relat as well to one another as to the elements of which t habitation is composed. Therefore, one mind l planned, or at least hath prescribed a general plan all these productions. One Being has been concer in all.

Under this stupendous Being we live. Our l piness, our existence, is in his hands. All we ex must come from him. Nor ought we to feel our si tion insecure. In every nature, and in every portio nature, which we can descry, we find attention besto upon even the minutest parts. The hinges in the w of an *earwig*, and the joints of its antennæ, are as hig wrought as if the Creator had had nothing else to fin We see no signs of diminution of care by multiplicit objects, or of distraction of thought by variety.

: no reason to fear, therefore, our being forgotten, or
·looked, or neglected.[80]

he existence and character of the Deity is, in every
, the most interesting of all human speculations. In
, however, is it more so, than as it facilitates the
f of the fundamental articles of *Revelation*. It is a
to have it proved, that there must be something in
world more than what we see. It is a farther step
now that, amongst the invisible things of nature,
must be an intelligent mind, concerned in its pro-
ion, order, and support. These points being assured
s by Natural Theology, we may well leave to Re-
tion the disclosure of many particulars, which our
rches cannot reach, respecting either the nature of
Being as the original cause of all things, or his cha-
r and designs as a moral governor; and not only so,
the more full confirmation of other particulars, of
h, though they do not lie altogether beyond our
nings and our probabilities, the certainty is by no
s equal to the importance. The true theist will be
first to listen to *any* credible communication of
ne knowledge. Nothing which he has learnt from
ral Theology will diminish his desire of further in-
tion, or his disposition to receive it with humility
thankfulness. He wishes for light: he rejoices in
. His inward veneration of this great Being will
ue him to attend with the utmost seriousness, not

There is assuredly nothing that more tends to absorb
whole faculties in devout admiration than the contem-
n of that universal power and pervading skill which
re remarked by the author. The same Being that
oned the insect whose existence is only discerned by a
scope, and gave that invisible speck a system of ducts
ther organs to perform its vital functions, created the
nous mass of the planet thirteen hundred times larger
our earth, and launched it in its course round the sun,
l the comet, wheeling with a velocity that would carry
nd our globe in less than two minutes of time, and yet
ving through so prodigious a space that it takes near
nturies *to encircle the sun!*

only to all that can be discovered concernin searches into nature, but to all that is taught tion which gives reasonable proof of havin from him.

But, above every other article of reveal does the anterior belief of a Deity bear with force upon that grand point, which gives ind and importance to all the rest,—the resurre human dead. The thing might appear hop not see a power at work adequate to the eff under the guidance of an intelligent will, a penetrating the inmost recesses of all subst far from justifying the opinion of those who a thing incredible that God should raise the I admit that it is first necessary to be pe there *is* a God to do so. This being thoro in our minds, there seems to be nothing in (concealed as we confess it to be) which ne our belief. They who have taken up the the acts of the human mind depend upon that the mind itself indeed consists in org supposed to find a greater difficulty than admitting a transition by death to a new stat existence, because the old organisation is ap solved. But I do not see that any impracti be apprehended even by these; or that the upon their hypothesis, is far removed from t some other operations which we know with the Deity is carrying on. In the ordinary plants and animals from one another, a parti cases, minuter than all assignable, all concei sion,—an aura, an effluvium, an infinitesi mines the organisation of a future body: than fix, whether that which is about to shall be a vegetable, a merely sentient, being; an oak, a frog, or a philosopher; m differences; gives to the future body its nature, and species. And this particle, springs, and by which is determined, a *nature, itself* proceeds from, and owes its c

prior body: nevertheless, which is seen in plants most
ecisively, the incepted organisation, though formed
rithin, and through, and by, a preceding organisation,
s not corrupted by its corruption, or destroyed by its
lissolution: but, on the contrary, is sometimes extricated
nd developed by those very causes; survives and comes
nto action, when the purpose for which it was prepared
equires its use. Now an economy which nature has
dopted, when the purpose was to transfer an organisa-
ion from one individual to another, may have something
nalogous to it when the purpose is to transmit an or-
anisation from one state of being to another state: and
hey who found thought in organisation may see some-
hing in this analogy applicable to their difficulties; for
whatever can transmit a similarity of organisation will
nswer their purpose, because, according even to their
wn theory, it may be the vehicle of consciousness, and
ecause consciousness carries identity and individuality
long with it through all changes of form or of visible
ualities. In the most general case, that, as we have
id, of the derivation of plants and animals from one
other, the latent organisation is either itself similar to
e old organisation, or has the power of communicating
new matter the old organic form. But it is not re-
icted to this rule. There are other cases, especially
he progress of insect life, in which the dormant or-
isation does not much resemble that which encloses
nd still less suits with the situation in which the en-
ng body is placed, but suits with a different situation
hich it is destined. In the larva of the libellula,
h lives constantly, and has still long to live under
, are descried the wings of a fly, which two years
ards is to mount into the air. Is there nothing in
alogy? It serves at least to show, that, even in
servable course of nature, organisations are formed
neath another; and, amongst a thousand other in-
, it shows completely that the Deity can mould
ion the parts of material nature, so as to fulfil any
whatever which he is pleased to appoint.
who *refer the* operations of mind to a substance

totally and essentially different from matter (as most certainly these operations, though affected by material causes, hold very little affinity to any properties of matter with which we are acquainted), adopt perhaps a juster reasoning and a better philosophy: and by these the considerations above suggested are not wanted, at least in the same degree. But to such as find, which some persons do find, an insuperable difficulty in shaking off an adherence to those analogies, which the corporeal world is continually suggesting to their thoughts; to such, I say, every consideration will be a relief, which manifests the extent of that intelligent power which is acting in nature, the fruitfulness of its resources, the variety, and aptness, and success of its means; most especially every consideration which tends to show that, in the translation of a conscious existence, there is not, even in their own way of regarding it, any thing greatly beyond, or totally unlike, what takes place in such parts (probably small parts) of the order of nature, as are accessible to our observation.

Again: if there be those who think that the contractedness and debility of the human faculties in our present state seem ill to accord with the high destinies which the expectations of religion point out to us; I would only ask them, whether any one who saw a child two hours after its birth could suppose that it would ever come to understand *fluxions*;* or who then shall say, what further amplification of intellectual powers, what accession of knowledge, what advance and improvement, the rational faculty, be its constitution what it will, may not admit of when placed amidst new objects, and endowed with a sensorium adapted, as it undoubtedly will be, and as our present senses are, to the perception of those substances and of those properties of things with which our concern may lie.

Upon the whole: in every thing which respects this awful, but, as we trust, glorious change, we have a v
and powerful Being (the author, in nature, of infinit

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* See Search's Light of Nature, passim.

expedients for infinitely various ends), upon
ɔ rely for the choice and appointment of means
to the execution of any plan which his goodness
ıstice may have formed for the moral and ac-
e part of his terrestrial creation. That great
ts with *him:* be it *ours* to hope and to prepare,
firm and settled persuasion, that living and
are his; that life is passed in his constant pre-
at death resigns us to his merciful disposal.

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PALEY'S

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WITH

ILLUSTRATIVE NOTES,

BY

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AND AN INTRODUCTORY

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BY SIR CHARLES BELL.

WITH NUMEROUS WOODCUTS.

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APPENDIX.—I.

ILLUSTRATIONS

OF

PALEY'S
TURAL THEOLOGY.

BY

CHARLES BELL, K.G.H., F.R.S., L. & E.

NATURAL THEOLOGY.

I.

MECHANISM OF THE FRAME.

[illegible]RCHDEACON PALEY has, in two introductory chapters [illegible]f his Natural Theology, given us the advantage of sim[illegible]e, but forcible language, with extreme ingenuity, in [illegible]ustration. But for his example, we should have felt [illegible]e hesitation in making so close a comparison between [illegible]ign, as exhibited by the Creator in the animal struc[illegible]re, and the mere mechanism, the operose and imperfect [illegible]trivances of human art.

Certainly there may be a comparison; for a superficial [illegible]d rapid survey of the animal body may convey the [illegible]tion of an apparatus of levers, pulleys, and ropes, [illegible]hich may be compared with the spring, barrel, and [illegible]ee, the wheels and pinions, of a watch. But if we [illegible]dy the texture of animal bodies more curiously, and [illegible]pecially if we compare animals with each other—for [illegible]mple, the simple structure of the lower creatures with [illegible]e complicated structure of those higher in the scale of [illegible]istence—we shall see that, in the lowest links of the [illegible]in, animals are so simple, that we should almost call [illegible]em homogeneous; and yet in these we find life, sensi[illegible]lity, and motion. It is in the animals higher in the [illegible]le that we discover parts having distinct endowments, [illegible]d exhibiting complex mechanical relations. The me[illegible]nical contrivances which are so obvious in man, for [illegible]ance, are the provisions for the agency and dominion [illegible]n intellectual power over the materials around him.

mark this early, because there are authors who, upon this complexity of mechanism, confound it he presence of life itself, and think it a necessary t—nay, even that life proceeds from it; whereas echanism which we have to examine in the animal is formed with reference to the necessity of acting , or receiving impressions from, things external to ody, a necessary condition of our state of existence material world.

any have expressed their opinion very boldly on the essary relation between organisation and life, who e never extended their views to the system of nature. place man, an intelligent and active being, in this rld of matter, he must have properties bearing relation that matter. The existence of matter implies an ency of certain forces; the particles of bodies must ffer attraction and repulsion, and the bodies formed by e balance of these influences upon their atoms or particles must have weight or gravity, and possess mechaical properties. So must the living body, independently f its peculiar endowments, have similar composition and qualities, and have certain relations to the solids, fluids, gases, heat, light, electricity, or galvanism, which are around it. Without these, the intellectual principle could receive no impulse—could have no agency and no relation to the material world. The whole body must gravitate or have weight, without which it could neither stand securely nor exert its powers on the bodies around it. But for this, muscular power itself, and all the appliances which are related to that power, would be useless. When, therefore, it is affirmed that organisation or construction is necessary to life, we may at least pause in giving assent, under the certainty that we see another and a different reason for the construction of the body. Thus we perceive, that as the body must have weight to power, so must it have mechanical contrivance, or gement of its parts. As it must have weight, so it be sustained by a skeleton; and when the t which give the body height and d a (for in that sense a bone irst taken) adjusted with the finest attention to the pendicular weight that it has to bear, as well as to ateral thrusts to which it is subject in the motions of body.

The bones also are as levers, on the most accurate hanical principles. And whilst these bones are neces give firmness and strength to the frame, it is admir observe that one bone never touches another, bu ne elastic material, the cartilage, intervenes betw their ends, the effect of which is to give a very consi ble degree of elasticity to the whole frame. With ch elasticity a jar would reach the more delicate org ven in the very recesses of the body, at every vio otion; and, but for this provision, every joint w reak by the attrition of the surfaces of the bones. ones are surrounded with the flesh or muscles. uscle is a particular fibrous texture, which alone, of he materials constituting the frame, possesses the pe iar inherent power or endowment of contracting; i this power which we are to understand when professi men speak of irritability. The contraction of the mu bears no proportion to the cause which brings it i operation, more than the touch of the spur upon horse's side does as a mechanical impetus to the f with which the animal propels both himself and ri Each muscle of the body—and by common estimate t are hundreds—is isolated; and no property of motio propagated from one to another; they are distinct ins ments of motion. The muscles surround the bones, are so beautifully classed, that in every familiar motio the limbs some hundreds of them are adjusted in t exact degree, to effect the simplest change in the posi of the body.

Each fibre of a muscle, and a muscle may con millions of fibres, is so attached to the tendon, that whole power is concentrated there; and it is the ten of the muscles *which*, like ropes, convey the force of *muscles to the bones.* The bones are passive levers *muscles are the active* parts of the frame.

With all the seeming intricacy in the

crossing of these tendons, they are adjusted accuratel
mechanical principles. Where it is necessary, the
in sheaths, or they receive new directions by lateral
mentous attachments, or there are placed under
smooth and lubricated pulleys, over which they run
where there is much friction, there is a provision
in effect to the friction-wheel of machinery.

Thus the bones are levers, with their heads most
ously carved and articulated, and joined to the intr
relations of the muscles and tendons, they present o
whole a piece of perfect mechanism.

It is with this texture—the coarsest, roughest pa
of the animal frame—that our author is running a pa
when he compares it with the common mechanical
trivances of machinery. Whilst these grosser par
the animal body exhibit a perfection in mechanical a
ation far greater than the utmost ingenuity of man
exhibit in his machinery, let the reader remember
they bear no comparison with the finer parts of the
mal body; such, for example, as the structure of
nerves which convey the mandate of the will t
moving parts, or of the vessels which are conveyin
blood in the circulation, and where the laws of hydr
may be finely illustrated; or of those secreting
where some will affirm the galvanic influence is in
tion with something finer than the apparatus of
and troughs.

But were we to institute a comparison betwe
mechanical contrivances of man and these fine
chanisms in the animal frame, we must recolle
there are structures in the body much more admira
we shall have abundant opportunities of showing
proceed in the present volume. The organs of the
which are so many inlets for the qualities of surro
matter to excite corresponding sensations and perce
will afford us delightful subjects of contemplatio
proofs more conclusive of design in the human bo
only in regard to the system of that body itself, bu
forms a part of the system of the universe.

II.

DESIGN AS EXHIBITED IN THE MECHANICAL STRUCTURE OF ANIMAL BODIES.

animal bodies, besides those structures on which conomy and much of their vital functions depend, is a firm texture necessary. Without this, the ble would have no characteristic form; and ani- ould want the protection necessary for their deli- gans, and could not move upon their extremities. ave to show with what admirable contrivance, in ferent classes of organised beings, this firm fabric ed, sometimes to protect the parts, as a shell, and mes to give them form and motion, as in the ske-

regetables, as in animals, there is a certain firm il necessary to support the parts which are the active organs of their system, and which are so ul and interesting. The ligneous or woody fibre nute, elastic, semi-opaque filament, which, closing adhering to other filaments of the same kind, the grain or solid part of the wood. The best stration of the office of the woody fibre is in the When the leaf of a plant is prepared by macera- nd putrefaction, and the soft part washed away, emains an elegant skeleton of wood, which retains m of the leaf, and which is perfectly well suited ort its delicate organisation. It is the same sub- which, when accumulated and condensed, gives nd strength to the roots and branches of the oak; ese, though fantastic and irregular in their growth, re a mechanical principle of strength, as obvious to *p-builder in the* knees of timber, as in the delicate

the leaf. Lord Bacon speaks of "kne
is good for ships that are to be tossed." Th
, though not directly engaged in the livi
' the tree, is yet essential for extending th
nd leaves to the influence of the atmospher
elasticity under the pressure of the wind
at is equivalent to exercise for the motion
A tree opposed to winds and to a severe c
ense in its grain, and the wood is preferred b
man to that which is the growth of a mild

nnot miss seeing the analogy of the woody fibre
bones of animals. Bones are firm, to sust
nal's weight, and to give it form. They
and move under the action of muscles; and th
promotes the activity of the living parts, and
ry to health. But let us first observe the structur
e of the lower animals. It will be agreeable t
he hard material, though always appropriate and
t, becoming more and more mechanical and con
n its construction, from the lithophytes, testace
cea, reptiles, fishes, mammalia, up to man.
e texture of a sponge, its form and elasticity, de
upon a membranous and horny substance, to which
siliceous and calcareous spiculæ are added.
arbonate of lime is the hardening material of shell,
ed to a membranous or cartilaginous animal matte
author describes the slime of a snail hardening into
ll by the influence of the atmosphere; but this is a
y imperfect and, indeed, erroneous view of the matter.
e shell of the oyster, and even the pearl, consist of
ncentric layers of membrane and carbonate of lime;
d it is their lamellated arrangement which causes the
eautiful iridescence in the polished surface of these
hells.* In the rough outer surface of an oyster-shell
e shall see the marks of the successive layers. We
have to understand that that which now forms the centre

See the discoveries of Sir David Brewster on this sub
Phil. Trans. 1814, p. 397.

ad utmost convexity of the shell was, at an earlier stage, ufficient to cover the whole animal. But as the oyster rows it throws out from its surface a new secretion, omposed of animal matter and carbonate of lime, which s attached to the shell already formed, and projects farther at its edges. Thus the animal is not only protected by this covering, but, as it grows, the shell is made thicker and stronger by successive layers.

The reader will not be unwilling that we should stop here to show that, rudely composed as this covering of the oyster seems to be, it not only answers the purpose f protecting the animal, but is shaped with as curious a destination to the vital functions of respiration and obtaining food as anything we can survey in the higher nimals. We cannot walk the streets without noticing hat, in the fish-shops, the oysters are laid with their flat ides uppermost; they would die were it otherwise. The nimal breathes and feeds by opening its shell, and hereby receiving a new portion of water into the concavity of its under-shell; and if it did not thus open its hell, the water could neither be propelled through its ronchiæ or respiratory apparatus, nor sifted for its food. t is in this manner that they lie in their native beds; ere they on their flat surface, no food could be gathered, s it were, in their cup; and if exposed by the retreating de, the opening of the shell would allow the water to scape, and leave them dry, thus depriving them of respiration as well as food.*

We perceive, then, that the form of the oyster-shell, ude as it seems, is not a thing of chance. Since the hell is a cast of the body of the animal, the peculiar hape must have been given to the soft parts, in anticipation of that of the shell, an instance of prospective contrivance.

That the general conformation of the shell should ave relation to what we may term its function, will be less surprising when we find a minute mechanical intention in each layer of that shell. We should be inclined to say that the earthy matter of the shell crystallizes, were it not that the striated or fibrous appearance differs in the direction of the fibres in each successive stratum—each layer having the striæ composing it parallel to each another, but directed obliquely to those of the layer previously formed, and the whole exhibiting a strong texture arranged upon well-known mechanical principles.

---

* In confirmation of these remarks, the geologist, when e sees those shells in beds of diluvium, can determine whether the oysters were overwhelmed in their native beds, or ere *rolled away and* scattered as shells merely.

Shell is not alive, as true bone is. If the shell of any of the testacea be broken, the surface of the animal secretes a new shell, not, however, by the concretion of mucus, but by the regular secretion of a substance combined of earthy and gelatinous matter.* Delicate experiments have been made by steeping shells in diluted nitric acid, by which it is shown that the carbonate of lime is the earthy material of shells; and that, when that earth is dissolved in the acid, a gelatinous substance of the form of the shell remains.

Crustaceous animals, such as the lobster and crab,† have their shell formed of the same substances as the testacea, but with the addition of phosphate of lime to the carbonate of lime. A question may arise, How do these animals grow? It is said that they cast their shells and remain retired until a new shell is secreted; and Réaumur has given a very particular account of the process of separation in the cray-fish. Naturalists have not found these cast-off shells. If they be not cast, the animals must, at a particular season, have their shells so softened as to permit sudden expansion of their bodies within; yet it would be difficult to say by what internal means this shell could be thus softened and made pliant. We presume the reason that the shells of the crustacea are not found in our museums is because they are not thrown off at once, but that the portions are detached in succession. In these crustacea we find an approximation to bone, inasmuch as the shell is articulated, and has certain processes directed inwards to which the muscles are attached.

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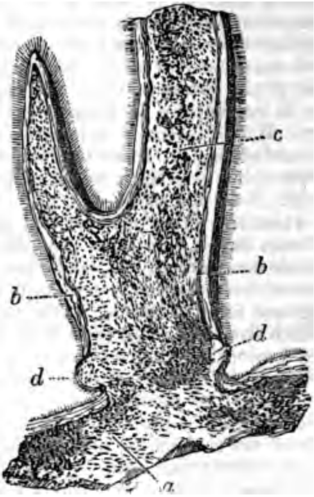
* We owe our knowledge of the formation of shell to the great French naturalist Réaumur, who, by ingenious experiments, showed the distinction of shell and bone, and that the former was secreted from the surface of the animal.

† *Vol. ii. p.* 224.

The hardening material of bone is the phosphate of lime, and this earthy substance is not merely united with cartilage or gelatinous matter, but membranes and vessels enter into the composition of bone. Bone is not excreted or thrown out of the system of the animal body, but, on the contrary, it participates in those laws that govern living matter. It is continually undergoing the changes of deposition and absorption, under the influence of blood vessels and absorbing vessels, by which means it grows with the growth of the soft parts.

In fishes, which live in an element that supports the weight, the bones have a very large proportion of elastic cartilage in their composition, and some have so little of the phosphate of lime in their bones, as to be denominated cartilaginous fishes. Indeed, in the higher classes of animals which live upon land, there is in the different bones a finely appropriated union of earth, cartilage, and fibre, to give them the due proportion of resistance, elasticity, and toughness. Not only is the bone of each class of animal peculiar in the proportion of the ingredients, but each bone of the skeleton, as of man, has a due proportion of earth, and cartilage, and fibre, to suit its office. The temporal bone, in which the ear is situated, is as dense as marble (it is called *os petrosum*), and of course is suited to propagate the vibration of sound: the heel-bone, or the projection of the elbow, on which the powerful muscles pull, is, on the other hand, fibrous, as if partaking of the nature of a tendon or rope; whilst the columnar bones, which support the weight, have an intermediate degree of density and an admirable form, as we shall see presently.

Let us consider the structure, growth, and decay of the deer's horns, as an example of the most rapid growth of bone, and a curious instance of its appropriation to a particular purpose. And, first, why should these antlers be deciduous, *falling at* an appointed season? The breeder of domestic cattle and horses endeavou pagate the favourite qualities of fleece or ca speed or power, by crossing. Nature accompl purpose by giving to the strongest.



[Section of the Root of a Deer's Horn.]

The antlers of the stag which is in mat vigorous health grow with the greatest spread and crotches; with the growth of the horn th crease of strength in the neck and shoulder.* not be surprised then, that, in contention with he that carries the largest antlers should obtain over the herd. After the season his antlers fa find the stag feeding with the other ma he had driven off. Be this, however, a

carotid artery, which nourishes the head size during the growth of the antlers.

The growth and fall of the horn is a remarkable phenomenon, and deserving further consideration.

The horn of the deer is bone, and is formed as an ternal part, that is to say, it is covered during its grow It grows from the outer table of the skull, *a*; but t extends, at the same time, from the integuments of head, a soft vascular covering, *b*, like velvet, so t during the whole period of its growth, the horn, *c*, around it a tender soft covering, full of vessels, and w is necessary to its growth and support. But when horn has acquired its full form and strength, this ve covering is destroyed by a very curious process. At root of the horn, near the skull, a circlet of tubercle called the burr or pearl, is found; the principal ve run between these tubercles, and, as the tubercles gr they close in upon the ascending blood-vessels, comp them, and prevent their conveying blood to the h then the membrane, which was vascular, becomes in sible and dead, and in time is rubbed off.

In old treatises on hunting, the separation of the o cuticle, or velvet, is called fraying; and the hunts in leading on his hounds upon a hart of many "tin judges of his size and strength by the fraying-post— height of the tree against which he has been butting rubbing his horns to separate the outer covering. horns, when the velvet is detached, are now perfect. is after this that the stag seeks the female in the d of the forest; and now it is that, in encountering rivals, fierce contests ensue. They dart against other with great fury, take no repose, and in a very weeks become quite exhausted. In the museum of College of Surgeons there are two superb sets of ant entangled and wedged together; they belonged to males, which had struck so fiercely against each ot that they could not withdraw their horns, and being strangely locked together, they starved, and were f dead. The stag is a very different animal, in regar strength, at different seasons of the year. He f on different herbage, sometimes preferring the heath; *at another season* he resorts to cop

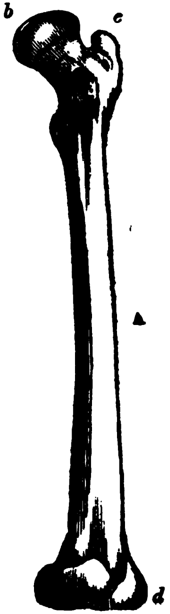
and corn-fields; and these correspond with his diff
condition as to strength and fatness, and with his pas
It is after the period of contention that the stag is
more found in the copses and underwood, feeding p
fully with his former rivals. And now the proce
absorption takes place at the root of the horns, and
are shed: sometimes one is carried a considerable
after the other is fallen; and it is observed that the
and strongest harts shed their antlers the soonest.
remarkable circumstance is, that such is the prov
through the absorption at the root of the horn, t
slight shock will now detach that which bore the u
force of the two combatants before. The fallow
have the same habits and passions; but they will co
in herds for favourite pasture-grounds, and divide
parties under the oldest and strongest of the herd.
can doubt that the antlers are for a temporary pur
since, for the greater part of the year, they are e
wanting, or in a tender state of growth? Nature be
them only as arms for the combat which is to decid
the strongest, and give a sire to the herd.

We shall now advert to the forms of the bones o
greater animals, and to those of man. That the l
which form the interior of animal bodies should hav
most perfect shape, combining strength and light
ought not to surprise us, when we find this in the l
vegetable production.

A reed, or a quill, or a bone, may be taken to
that in nature's works strength is given with the
possible expense of materials. The long bones o
mals are, for the most part, hollow cylinders, fille
with the lightest substance, marrow; and in bird
object is attained by means (if we may be permitt
say so) still more artificial. Every one must hav
served that the breast-bone of a fowl extends alon
whole body, and that the body is very large com
with the weight: this is for the purpose of renderin
creature specifically lighter and more buoyant in th
and that it may have a surface for the attachme
muscles equal to the exertion of raising it on the

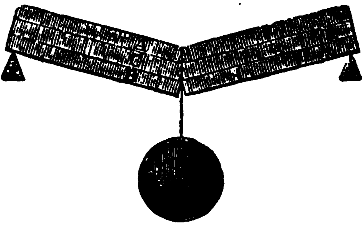
ation of lightness with increase of volume is
ir-cells extending through the body, and
ng by tubes between the lungs and cavities
. By these means the bones, although large
to withstand the operation of powerful
a them, are much lighter than those of qua-

· bones of the human body, being hollow
lled cylindrical, though they are not accu-
reason of which we shall presently explain;



f the femur, or thigh-bone, to show the hollow of the
ancellated *structure of its* upper and lower ends; b, the
it is articulated to the pelvis; c, the great trochanter.
which it is articulated to the leg.]

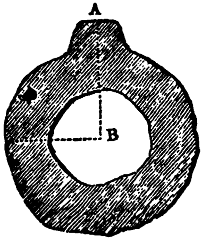
and we shall at the same time show that their irr larities are not accidental, as some have imagined. let us first demonstrate the advantage which, in structure of the bones, is derived from the cylind form, or a form approaching to that of a cylinder. piece of timber supported on two points, thus—



bear a weight upon it, it sustains this weight by d ent qualities in its different parts. For exan divide it into three equal parts (A, B, C): the u part A supports the weight by its solidity and resist to compression; the lowest part B, on the other l resists by its toughness or adhesive quality. Bet the portions acting in so different a manner, there intermediate neutral or central part C, that ma taken away without materially weakening the t which shows that a hollow cylinder is the for strength. We may observe a further illustration o when a tree is blown down and broken at the sten the windward the broken part gapes; it has been asunder like the snapping of a rope: to the leewarc of the tree the fibres of the stem are crushed intc another and splintered; whilst the central part is This, we presume, must always be the case, mo less. We may observe, too, why the arch is the of strength. If this transverse piece of timber we the form of an arch, and supported at the extrem then its whole thickness, its centre, as well as the u and lower parts, would support weight by resisting pression.

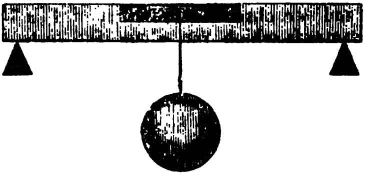
ıe demonstration may be carried much farther, the form of strength in the bone. If the part ylinder which bears the pressure be made more ıe power of resistance will be much increased; if a ligamentous covering be added on the e, it will strengthen the part which resists ex- and we observe a provision of this kind in the gaments which run along the vertebræ of the

we see the bone cut across, we are forced to ·dge that it is formed on the principle of the –that is, that the material is removed from the nd accumulated on the circumference, thus—



a spine or ridge, A, running along the bone, ich, when divided by the saw in a transverse , exhibits the irregularity, whereof A is the

ection of this spine shows a surface as dense as hat part is, therefore, much more capable of compression than the other part of the cylinder, common bone. This declares what the spine he anatomists must be wrong who imagine that is moulded by the action of the muscle, or that is a mere ridge, arising by accident among the It is, on the contrary, a strengthening of the the direction on which the weight bears. If ne *the experiment* with the piece of timber, we shall learn why the spine is harder than the rest o bone. If a portion of the upper part of the timb cut away, and a harder wood inserted in its place insertion of the harder portion of wood increases property of resistance. With this fact before u



may return to the examination of the spine of b We see that it is calculated to resist pressure, first, cause it is farther removed from the centre of the cy der, and, secondly, because it is more dense, to r compression, than the other parts of the circumfer of the bone.*

This explanation of the use of a spine upon a b gives a new interest to osteology. The anatomist ou to deduce from the form of the spine the motions of limb, the forces bearing upon the bone, and the na and the common place of fracture ; while, to the gen inquirer, an agreeable process of reasoning is introdu in that department, which is altogether without inte when the "*irregularities*" of the bone are spoken o if they were the accidental consequences of the pres of the flesh upon it.

Although treating of the purely mechanical princ it is perhaps not far removed from our proper obje remark that a person of feeble texture and ind habits has the bone smooth, thin, and light; but nature, solicitous for our safety, in a manner whic could not anticipate, combines with the powerful

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* As the line A B extends farther from the centre *B C*, on the principle of a lever, the resistance to trans *fracture* will be greater in the direction A B than B C.

lar frame a dense and perfect texture of bone, where
ery spine and tubercle is completely developed. And
us the inert and mechanical provisions of the bone
ways bear relation to the living muscular power of the
mb, and exercise is as necessary to the perfect consti-
tion and form of a bone as it is to the increase of the
uscular power. Jockeys speak correctly enough when
ey use the term "*blood and bone*," as distinguishing
e breed or genealogy of horses; for blood is an allow-
ble term for the race, and bone is so far significant, that
e bone of a running horse is remarkably compact com-
ared with the bone of a draught horse. The reader
an easily understand, that in the gallop the horse must
ome on his fore legs with a shock proportioned to the
pan; and that in the horse, as in man, the greater the
uscular power the denser and stronger is the bone.
he bone not being as a mere pillar, intended to bear a
erpendicular weight, we ought not to expect uniformity
its shape. Each bone, according to its place, bears
p against the varying forces that are applied to it.
onsider two men wrestling together, and then think
ow various the direction of the resistances must be:
ow they are pulling, and the bones are like ropes; or
gain, they are writhing and twisting, and the bones
ear a force like the axle-tree between two wheels; or
hey are like a pillar under a great weight; or those
ones are acting as levers. We see, therefore, why, to
ithstand these different shocks, a bone should consist,
s we have stated, of three parts, the *earth* of bone (sub-
hosphate of lime) to give it firmness; *fibres* to give it
ughness; and *cartilage* to give it elasticity.

We may pursue this subject a little farther still, taking
he text of our author—"*The proportioning of one thing*
another." Chap. xvii. sec. v.

The great functions by which animals live and breathe
d are nourished are the same through the whole chain,
om the simplest polypus or mass of jelly that floats in
e sea, to the largest and most complex of all terrestrial
eatures. The appetite for food, the powers of assimi-
ion, *circulation, aëration* secretion, are the same

functions in all living creatures, only modified by the size or condition. When we consider the astonishing variety in the shapes of animated beings, we are apt to forget the necessity of apportioning their size and strength, not only to the vegetable productions and the materials found on the surface of the earth, but to the magnitude of the globe—to the "great motions that are passing in the heavens." On that plan of living structure which pervades all the varieties of animals in which bones afford resistance and muscles activity, there must be a limit to stature. The resisting parts of the smaller animals, which have an external covering instead of bones, have comparatively much less material in them than the larger. Accordingly, philosophers have contrasted the power of the flea with that of the horse, deciding greatly in favour of the former. The rationale of this is not quite apparent at first; but a little consideration will convince us, that the resisting material being exterior to the animal's body, and consequently removed from the centre, it must possess more power against transverse fracture, as well as bestow a mechanical advantage for the action of the muscles. But this is not all: any degree of density and strength may be given to it, from its being a mere secretion, and being unorganized. We may compare, however, the bones of man with those of the elephant, or other huge animals.* Now it would seem that the material of bone (which we must recollect is porous, since it constitutes a living part, and is nourished by blood-vessels) could not, by any variety of conformation, bear up a greater mass than that of the elephant. On examining the bones of these immense animals, including the megatherium and rhinoceros, they are dense and strong, and clumsy, as we would term it; their spines and processes are large, and their cavities filled up, all which indicates, that to support a larger animal on extremities, some other material than the [illegible]lar bone would be required. Those immense bones are found in digging the earth, and which, in ages, have given rise to strange fancies, are the of animals inhabiting the water—whales or rep- whose bulk was extended in the water, or that ed on their bellies, and they could never have support sufficient to have raised their enormous it on extremities. With regard to the position, ‘a chicken roosting on its perch is related to the es revolving in the firmament,” I have elsewhere ated the necessity of a fixed point from which the es can act, and that the necessity of resistance es that of weight, and that that weight must be rtioned to the mass of the globe we inhabit, as as to the power of the muscular frame.*

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* Vol. iii. p. 7.

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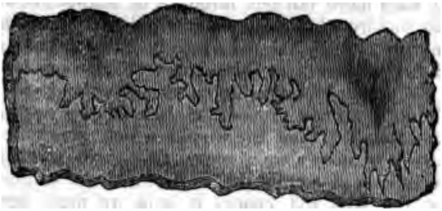
ee the introduction to the Bridgewater Treatise on Hand.”

III.

DESIGN OR MECHANICAL CONTRIVANCE AS EXHIBITED I THE BONES OF THE HEAD AND THEIR JOININGS.

We have elsewhere spoken of the "architecture" of th skull, which, though at first a startling term, has bee acquiesced in from the remarkable instances that w have given of design, in comparing the texture and co nexion of the bones with the art of the builder and ca penter. The more important the part is to life—th more vital the organ, we find the texture or fabric whic protects it the more perfect. The human skull present us with many curious proofs that the forces or injuries t which it is exposed are calculated and provided agains But we shall take our first examples from the skulls o animals; and here we see that the brain is not covere in the same manner in all, but that in each variety the is a provision against the forces to which the skull is sub jected. The skull of a dog is hardly in any respect lik the skull of a ram; the bones of the former are thin the line of union, which is called the *suture*, is simple it is not provided to withstand percussion: but in th latter animal there is reared over the proper brain-ca a series of arched cells of strong bone, and each bone joined to another by a line, serrated, deep, and regular the mechanical strength of the union always correspond ing with the strength of the bones; and the whole bein formed into a base suited for the support of the horn and calculated to sustain the shock when the anima butts with the whole weight and strength.

We might contrast the skull of the ram or goat wit that of the tiger, where the strength is in its jaw *This animal*, too, has the brain-case small, and, as i



e engraving represents the irregular line of union of the bones of the skull as seen on the outer surface.]

re, buried in the head; but the jaws, instead of being
ngy bones, as in man, are dense and strong to sustain
teeth; for what would avail these teeth, long and
rp and strong, could they be twisted from their
ket? and what would avail the strength of the jaws,
l length and depth of the teeth, were not the proper
ll surrounded with spines and arches of bone dense
l strong enough to give attachment to the muscles of
jaws? Thus, in the carnivorous animal, the strength
the bony textures of the head is all concentrated in
jaws of the animal, and corresponds with its instinct
hold and rend its prey.

But when the lion or the tiger have struck down their
ey—and have gorged themselves and sought their
ns, and when the lesser carnivorous animals have
ared the bones—there remains a rich repast which
y cannot reach; then comes the hyæna, which cracks
bones, and feeds upon the marrow.

Of all the skulls that can be collected in a museum,
jaws and teeth of the hyæna exhibit the most extra-
linary strength: the bones having a clumsy form and
nse texture quite peculiar, and suited for the socketing
the strong conical teeth.

We see, therefore, that the fabric of the head, taken
a whole, bears a certain resemblance in all classes of
imals; but, though built upon the same general plan,
supports are given to fortify the points which bear
shock. . · · ·

By such more obvious instances of adaptation we a led to inquire whether any similar adjustment of the resisting property of the bone is to be found in the h head. We must carry this along with us in our inquiry that a shock or vibration going through the great mas of the human brain proves more immediately destructiv of the faculties, than the wound which penetrates t substance without a concussion. When we contempl the condition of a child, its fearlessness, its restless activity, the falls and knocks it gets, we must perceiv that were not the textures of the bones and the bra adjusted, the child when it fell must have lain insensib instead of rising and crying more from terror than th sense of injury.

We may contrast this condition of the child with th of an old man losing his balance and falling on his he who lies insensible from the shock. Is it not appare that there is here a calculation of the accidents of li and a provision against them, which yet leaves u threatened with danger, and, therefore, on our guard?

The difference in the textures of youth and age are instructive as to the causes of the diversity. The brain of the old man is firm; the vibration injures its fibre. The brain of the child is soft, and in infancy it may be moulded to any shape. Then, again, the texture of the bone is entirely different, and hardly like the same substance. It is thin and pliant in the child, actually dimpled by a blow; whilst in age it is brittle from its density, and the vibration of the blow runs round it; or if it be broken, it is like a piece of sharp glass entering the tender parts beneath.

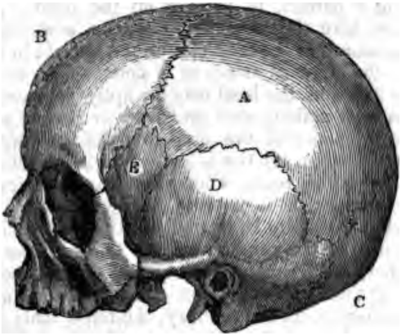
Much more than will stand inquiry has been said of the forms of the head, in reference to the contained organs; but there is a simple demonstration which should precede all this: the forms of the skull bear a relation to pressure and injury from without, and the parts most exposed are most protected. A man falling backwards has the back of his head exposed to injury; and the examination and section of the bone at this part shows how nature has strengthened it, by giving it greater thickness and prominence, and by groining it within. We s

ing it; for there is nothing more resembling the
g groinings or arches of the ground-story of a great
ing, than the ridges of the skull at this part of
se, which cross at a centre corresponding with the
inence of the occiput.

front, the form of the skull exhibits a provision
ss distinct in its object. The parts of the forehead
1 are most prominent and exposed (*eminentiæ*
ıles) exhibit, on their section, a thicker and denser
; whilst the lower part of the forehead is formed
ls or sinuses, which, throwing off the outer wall of
cull from the surface of the brain, still more effectu-
rotects it.

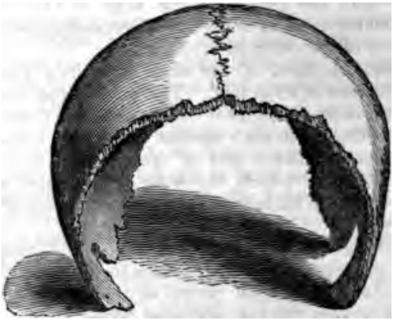
person tumbling sideways pitches on the shoulder,
he convexity of the head comes to the ground pre-
on that point (the centre of the parietal bone)
e the bone is thickest and most dense.

is, on the whole, impossible to study the forms of
ead without acknowledging that the shape, thick-



A. The *parietal* bone.
B. The *frontal* bone.
C. The *occipital* bone.
D. The *temporal* bone.
E. The *sphenoid* bone.

ness, and texture of the skull have reference to t
liability to pressure and blows from without.



[The figure represents the two parietal bones—forming an arch,
surmounted dome.]

To take a further example:—It seems very natu
in carrying a burden, to poise it on the head. N
whether we take the carpentry (called a *centering*)
which the stones of the arch of a bridge are laid in bu
ing it, or the arch of stone, or a dome—(for with
these the bones of the head may be aptly compared
there has been nothing ever contrived so perfect as
joining of the bones of the head to resist both pres
above, and straining at the sides. And if, on this
ject, we solicit the reader's attention more particul
to these joinings, it is because, in books merely
tomical, they are apt to be treated like things of accid
and described as the running of the fibres of one
into another, the necessary consequence of their mod
growth; or the accidental effect of the pressure of
muscle: whereas, on the contrary, the finest tools of
carpenter could make nothing so perfect or so den
strative of design.*

* This subject is pursued in more detail in the tre

These provisions would surely have met with earlier ttention had men contemplated in a true view the object f the animal frame-work; which is not to give absolute ıfety against inordinate violence, but to balance the hances of life,—leaving us still under the conviction, ıat pain and injury follow violence: so that our exerience of the injury, and our fear of pain, whilst they e the principal protection to life, lay the foundation of nportant moral qualities in our nature.

iven as Appendix II. originally published by the Society r the Diffusion of Useful Knowledge, under the title of Animal Mechanics." It is there shown that the bony ıbstance of the skull separates, in the maturity of man, to two plates or tables, and of different degrees of hardss, with an intermediate soft substance; and that by this rangement of substances of different densities, a shell or vering is given for the protection of the brain, opposing fficient resistance to pressure, and at the same time calcuted to stifle vibration from a blow.

IV.

OF THE JOINTS.

In comparing the skeleton with carpentry,
artificial that admits of comparison with it,
that, in the bones, there is not a straight line
form, whether they serve as a shaft, axle,
while, in the other, every part is levelled a
or formed according to some geometrical cu
would lead a superficial thinker to conclud
bones were formed irregularly, or without
principle; but the consideration of by Wh
leads to a review; and a deeper examination
it the conviction that the curves, spines, an
ances of the bones are formed with a rela
weight which they bear, and the thrusts an
which they are subjected in the different mo
body.

If we observe the various postures of a
manual labour, or under a weight, or running,
or wrestling, we shall be convinced that no c
the bones, formed upon geometrical lines or c
suit all this variety of motion. No splicing,
cogging, or any of all the various shapes into
carpenter or joiner cuts his material, could e
to withstand the motions of the body, wh
utterly impossible to estimate the forces, or
upon the variety in the motion.

That the varieties in the forms of the bo
irregular, nor accidental, but are related to t
to be performed, is apparent in the close exa
the human skeleton, and still more clearly
comparative anatomy.

ıapes of the bones are very closely related to the to be performed by the different joints. Let us he enlargement of the diameter of the bone at an on. This expansion of the articulated surface ne gives power to the binding ligaments, by ; them from the centre of motion; and by the of surface and additional strength of ligament, er of dislocation is much diminished. The friction vo bodies whose surfaces move upon one another ıcreased by the extent of surface, the pressure ; the same. Hence the enlargement of the of the joint is attended with greater security there being additional friction. But, for the t, the surfaces of the bones, instead of sliding another, have a rounded form, and roll upon er. Now the friction, in this case, depends diameter of the body which rolls, and is small tion as the diameter of that body is great, the eing the same. By this we see that the large ming the knee-joint, for example, have every of greater strength without increased friction. uthor has perhaps dwelt sufficiently on the ss given to the articulating surfaces of the the cartilages and the synovial or lubricating garly called joint-oil (and ignorantly so called); these general observations, in order fully to nd the fine adjustment of each bone in its artiwe should require to go minutely into the ana- hen we should find with how curious a me- ıdaptation the motions are permitted in the pre- irection and checked in every other. We should to observe, also, how the motions of one joint d to those of another; and how, by the com- f joints, each of which is securely checked and ned, there is a facility and extent of motion by their combination: for example, in the arm , where the motions are free, and varied in sible direction.

teresting to see how the joints of the lower exare modified in man in comparison with those of the upper. We have elsewhere remarked that the bones of the human pelvis, thigh, and leg exceed those of all other animals in relative size, which shows a provision for the erect position of man. The same is evinced in the form of the joints, as the ankle, knee, and hip; for whilst their combinations give every necessary degree of motion consistent with security, there is a happy provision, producing at once firmness and mobility. That is to say, when the limb is thrown forward in walking or running, it is loose, and capable of being freely directed; so that we plant it with every convenience to the irregularity of ground: but when the body is carried forward to be perpendicular over the limb, it acquires, by the curious adjustment of the bones, a firmness equal to that of a post. Again, when the body is still further thrown forward, and the limb is disencumbered of the weight of the body, the joints are let loose so as to be bent easily, and to obey the action of the muscles.

V.

OF THE SPINE.

spine is the most perfect structure in the whole al machine. Perhaps, if our words were critically ı, it would be better to say, that the intention of :urious mechanical structure here was the most ap- ıt, and on that account most the object of our ration. By the skeleton is meant the collection of s which gives form and strength to the superior class imals; and as these bones are bound together by a ı of vertebræ, the whole class of these animals is d *vertebrata*, from this most essential part of the ›ton. Besides thus binding the bones together, and ing, as it were, the very centre of the whole, the › is a tube for protecting the most vital organ of all, ›pinal marrow. But, again, when we look upon the ›ton of man as giving him the power of standing t, we observe that the spine, whilst it retains its r offices, has a new one imposed upon it: it is a r for sustaining not only the superior parts of the ', but the globe of the head, which we shall find it ›cts in a very unexpected manner. The reason of admiration, then, is in being able to perceive the es by which these different offices are performed by construction of this column: how nature has esta- ıed the most opposite and inconsistent functions in set of bones;—for these bones are so strong as not ffer under the longest fatigue or the greatest weight ›h the limbs can bear; and so flexible, as to perform ›hief turnings and bendings of the body; and yet so ly withal, as to contain and defend the most material the most delicate *part* of the nervous system.

In some animals, the lowest of the vertebrata, protecting texture of the spinal marrow hardly des the name of vertebral column. In certain fishes,[*] example, the spine consists of a cartilage made toug ligamentous intertexture. In the myxine, this cart does not entirely enclose the spinal marrow; for i in a deep groove on the upper part of the spine. let us not suppose that in fishes there is any imperfe in the vertebral column: it is an elastic colum which the muscles act so as to become the mea powerful locomotion; and in all fishes the spine more or less, this remarkable elasticity. Ascendi the scale of animals, we find the cartilage formin spinal column subdivided by cavities which con gelatinous fluid; and these cavities being surro with a strong but elastic ligamentous covering, n can be conceived more admirably adapted to g springiness to the whole column. Still ascendin discover that the bony matter becomes deposited be these cavities; and here the separate vertebræ appear. If two vertebræ of the great shark be out together, and the sac between them punctured. is the elasticity of the walls of this sac, that th will be spouted out to a distance. In other fish the cod-fish (an osseous fish), the structure appro to that of the mammalia; the intervertebral subs is gelatinous. In the whales, circular concentric ments join the vertebræ, and a small portion i centre consists of a glairy matter. In mammalia, a man, there are strong and distinct bones of the vert and these are joined by a ligamentous cartilage, the circle of which is remarkably strong, and the centr and elastic. The toughness and strength of the ex circle, and the soft condition of the centre, make a equivalent in action to what might be produced by intervening between the surfaces: a facility of mot thus bestowed which no form of solid could give yet the joint is so strong, that the bone breaks but the ligamentous cartilage never gives way. ie veterinary surgeon casts a horse, if he be not restrain him, he will twist himself with a force ill break the vertebræ. It is a frequent accident but the texture that gives mobility to the spine elds.

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[*] Myxine, lamprey, sturgeon, &c.

ext thing admirable in the spine is the manner in e head is sustained on a column possessing elas- d in which the brain is thereby saved from un- ussion in the movements of the body. This object ained altogether through the elastic substance in which we have described; but it is owing, in a asure, to the general form of the spine in man. vertebræ been built up, like a lofty column, of put correctly and vertically over one another, would not have had the advantages which re- the structure that we have to describe. As the at weight would then have fallen on the centres bodies of the vertebræ, they must have yielded ht degree only. Accordingly, the figure of the s given to the column, which waving line we admire because it is the line of beauty, as some ned it, but because it is the form of elasticity. The ng already in a curved shape, it bends easily; the is directed upon the margins of the vertebræ and tervertebral substances, and they therefore yield and by yielding, they produce an increase of e, a consequent shortening of the whole column, it an easy return to their original places. Sup- rest the palm of the hand upon a walking-cane, elastic, but perfectly straight; it bears a con- pressure without yielding, and when it does is with a jerk; but if it be previously bent, we may increase or diminish the pressure, there no shock: the hand will be supported, or the eld, with an easy and uninterrupted resiliency. conceive to be the end obtained through the urvature of the spine: that the brain shall re- shock in the sudden motions of the body.

we to give our attention to the processes of bone which stand out from the bodies of the vertebræ, we should find unexpected provisions there also. It is a common remark of anatomists, that the bones of the spine are secured in their proper places by the relations of the surfaces in contact; the surface of the body being oblique in one direction, and those of the articulating processes in another—the one therefore preventing the bone being dislocated forwards, and the others preventing it being displaced backwards. There is something more than this. The articulating processes consist of two broad surfaces, which are inclined in such a manner that they slide upon one another—that is to say, the articulating surface of the vertebra above, being itself inclined, rests upon another which is also inclined. As the intervertebral substances of the bodies yield and recoil, the articulating process of the upper vertebra shifts upon the inclined surface of the process on which it is seated, ascending and descending; but the impediment is greater the more the vertebra descends, thus adding to the elasticity and security of the whole, and preventing the abrupt shocks which would be the consequence of the surfaces being horizontal. If a cannon were made to recoil upon an ascending plane, or a surface forming a portion of a circle, it would represent the mechanism of the articulating processes of the vertebræ.

Let the separate spine be presented before us, it stands up, like a mast, broad and strong below, and tapering upwards. The mast of a ship is supported by the shrouds and stays; and if we sought for an analogy with these, we must fix upon the long muscles of the back, which run along the spine to sustain it. But as a mast goes by the board in a storm, we see where the spine would have been most in danger, had not nature provided against it. When we start forward in walking or running it is by the exertion of the muscles of the lower extremities, and the body follows. Did the spine stand directly up perpendicularly, it would sustain a shock or jar at its base in these sudden motions. We see, therefore, the intention of the lower vertebræ being inclined forwards from their foundation on the sacrum: for by this means, the jar which might endanger the junction of the lowest piece, is divided amongst the five pieces that form the curve. The same thing is seen in the quadruped: for as the spine in the back and loins lies horizontally, and the neck rises towards the perpendicular, there would be danger of dislocation, if the vertebræ of the neck rose suddenly and abruptly from the body: there is, therefore, at the lowest part of the neck a sweep or semicircle formed by the junction of several vertebræ, to permit the head to be erected; a remarkable example of which is shown in the stag.

We have elsewhere observed, that when a delicate piece of mechanism is contrived by the hands of man, it may be locked up and preserved. But the most delicate textures of the living frame stand distinguished, above all, by this quality, that if they be not put to use, they very quickly degenerate. Not only is the faculty of action lost by inaction, as every one must be aware takes place in the functions of his own mind, and in the exercise of his senses, but the texture of the organs quickly degenerates. If by accident a limb should lose certain movements, the muscles, nerves, vessels, which nature intended to be subservient to these motions, become in a few weeks or months so wasted that they are hardly recognizable by the anatomist. If we apply this acknowledged principle to the spine, and take along with us that the texture of bone, cartilage, ligament, tendon, muscle, all the parts which enter into its structure and are necessary to its perfection, however varying in solidity or composition, retain their perfection by being exercised, we shall readily perceive the effect of confinement on young females. Without any positive disease, but from being over-educated in modes which require sedentary application, the spine becomes weak and loose in texture, and yields to the prevailing posture, whatever that may be. We mention this because it is a principle important in every consideration to each individual, and applicable to both body and mind.

The French philosophers have entertained the notion that the central parts of all animals are more pe in their construction, whilst the extremities are subject t variety—a theory partly admitted by some eminent phy- siologists among ourselves, and which introduces obsc rity and hypotheses into one of the most remarkable pro of design. Dr. Roget, in his excellent 'Bridgewater Treatise,' has taken up this idea.

A spinal marrow belongs to the whole of the verte brated class of animals; and the spinal marrow must b protected by bone: accordingly, as the principal use o the spine is permanent, so must its form be. Yet whe ever there is a change in the action, or rather in the p of the spine, we find the vertebræ conformable. Th the motion of a fish through the water results from a lateral movement of the tail and spine; but were the con- stituent bones formed like those of other animals of the same class, the lateral or transverse processes of the ver- terbræ would interfere with this motion: they are there- fore removed, and in order to give strength to the chain of bones, the spinous processes are prolonged towards the back, and corresponding processes project towards the viscera. In the cetacea, as the whale and dolphin, &c., the position of the tail is reversed; it lies out horizontally; and the vertebræ correspond. These animals must rise to breathe the air, and their tails are thus provided to raise them easily to the surface; a proof, if any were wanted, that the spine, the very centre of the system, is accommodated to the main function of respiration.

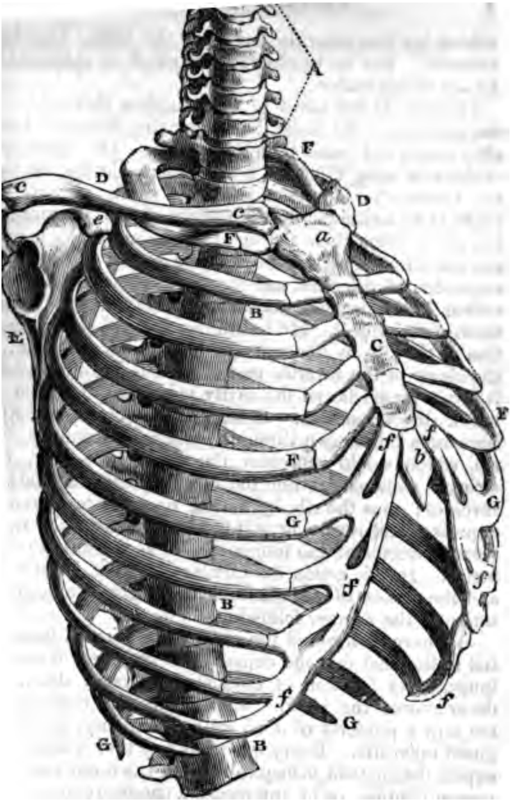
The tail of animals is the prolongation of the spine. But it seems extraordinary that any one should make this the ground of an hypothesis, that when parts are repeat- ed, they become more and more imperfect as they recede from the centre. It is however referred to in view, be- cause the bones constituting the tail become smaller and rounder, and terminate in cartilage in which there is no ne. Is it not, on the contrary, obvious that the tail of als is constituted for its proper purpose, firm towards ot, with muscles to play it in all directions, and less nd more elastic towards the end to carry the brush? nvthing be better adapted to such purposes? be more perfect if there were vertebræ instead of round bones joined together? In short, corresponding as this part does with its uses, sometimes as a brush to curl round the animal and be a mantle for warmth, sometimes as a rudder in running, sometimes as a fan, and always reaching where the ear or the tongue cannot reach —must all the obvious provisions be lost sight of in the consideration that animal bodies are constituted so imperfectly, that if a part like a vertebra be formed in the centre, repeated or prolonged, each link, as it recedes from the centre, must become less and less perfect, degenerating from what is presumed gratuitously to be its original form?

VI.

OF THE THORAX AND MECHANISM OF RESPIRA

OUR author might have made more use of the t
affording proofs of his great argument. We h
represented the spine, breast-bone, and ribs, as
tomist articulates them. Were he to make a sk
this fashion, it would be fragile in an extraordi
gree, compared with the natural body; and if the
fell, it would inevitably be broken. Let us se
what gives protection to the bones in the natur
The celebrated John Hunter was much eng
showing by what means elasticity came in aid of
cular power, both in the textures circulating th
and in those ministering to the play of the lun
may observe how the same principle conduces t
tection of the ribs as well as assists their moti
spiration.

The anterior part of the rib (*f*) which el
rib (F G) and joins it to the breast-bone (C),
of elastic cartilage; and the rib having a free
behind to the spine, it results that each rib is
of elasticity. The anatomist making no propo
for this in the artificial skeleton, the bone br
like a piece of china. We have another pro
tural body of the necessity for elasticity. W
served that a child, rash and unsteady, is lia
sand accidents to which those of maturer y
exposed. Now, during all the active year
whole textures of the frame, and especially
both bone and cartilage, possess elasticity,
with the hazards to which youth is subj
the child falls and suffers no injury; wher



rawing has been taken from an artificial skeleton, which is seldom d correctly. The ribs do not lie here in a natural position ; or, ey were placed so in the living body, it could only be in violent n, when they are raised to the very utmost. This figure is o at p. 91 of Vol. II., but the number of the Appendix is called ad of VI.]

striking his ribs upon the corner of the table, has the fractured. But let us observe the effect of elasticity i the act of respiration.

The ribs do not move to accommodate themselves t the motions of the lungs, but by moving draw the lung after them, and cause their expansion. The interstic of the ribs being filled up, and a septum closing the th rax below, the enlargement of the cavity permits t lungs to be expanded by the weight of the atmosphe the air entering them through the windpipe. We at o see the importance of the motions of the ribs, for t expansion of the chest and the play of the lungs. O author has, however, omitted an essential part of thi interesting subject. He has shown that the oblique pos tion of the ribs is necessary to inspiration, and that, b the rising of the anterior part of the rib, the breast-bo is thrust forwards and the cavity enlarged. But the ri has a double motion. It has a motion on its own axis. Suppose a line drawn through the two extremities of rib, which would represent the string of a bow, th string is stationary, while the bow, representing the ri revolves; thus the rib, by having its anterior extremit depressed and revolving as it is raised, enlarges the tran verse diameter of the thorax as well as the anterior dia meter. In this action the cartilage in front is twisted; and the torsion of this elastic matter affects the muscul action in the manner following.

We have understood the act of respiration to be esse tial to life, and that the expansion of the chest dilates t lungs, gives freedom of circulation through them, a decarbonizes the blood. It is interesting, therefore, see how a property of dead matter, elasticity, become guard upon life. Every one must feel that it is easie expire the air than to inspire it; and if we can imag person fainting, or in any mode in danger of death very word expiring, in its common sense, implies the last act of life is the expulsion of the breath), i elasticity tends to enlarge the chest, it must tend preservation of life, by restoring the circulation t *the lungs*. This is exactly what happens from the structure of the whole compages of the chest. The elastic property preserves the chest in a middle state. The muscles of inspiration act against the elasticity: the muscles of expiration also act against it: the elasticity tends, therefore, to maintain an intermediate state of dilatation of the thorax; and accordingly the lungs are preserved in a condition to perform their functions for a certain period at least, after the vital actions would have ceased through the muscles, had there been no such structure.

The great physiologist whom we have already mentioned, John Hunter, taught that when one part performed two functions, there was necessarily an imperfection. We have now the most suitable opportunity of controverting that position: for this texture of the thorax is subservient to many different functions. There is no imperfection evinced in the organ of smelling, because in order to draw in the odoriferous effluvia and make them pass over the olfactory nerve, we use the lungs. Nor do we experience any material interference with respiration, because we enjoy the power of speech through an impulse given to the air in expiration. Further, let us attend to the form and expansion of the chest as conducive to the motion and strength of the arm and hand. The motions of the superior extremity result from muscles which lie upon the chest; and were it not for the expansion of the chest, from the contained atmospheric air, these muscles would not act with sufficient power, or a substitute must have been found either of projecting bones, or of some solid texture, to afford lodgment and attachment to these muscles.

Then, again, considering man in his natural condition, the chances of life would run against him if he were incapable of floating upon water, or if the atmospheric air in his body were not anterior to his centre of gravity. The force of this argument will be understood when we remember that the air contained within the lungs, after a man has made an inspiration, amounts to three hundred and thirty cubic inches.

Looking to the means of guarding life, nothing can more important than the condition of the lungs, in respe to the atmospheric air within them. The sensibility and the rapid contraction of the glottis, which is at th mouth of the respiratory tube, is for the purpose arresting any foreign matter afloat in the atmospher which might be drawn in by the stream of inspired and so reach the recesses of the lungs. But were th all, the office would be but half performed. The forei body would be arrested; but how would it be expel if it lodged? In common expiration the air is no expelled altogether from the lungs: there is enough r tained to be propelled against this foreign body, and eject it. And, but for this, the sensibility of the glott and the actions of the expiratory muscles, would be vain; we should be suffocated by the slightest husk seed, or subject to deep inflammation by the collecti of foreign matter drawn into the air-tubes.

We may here observe, that the instinctive actions the protection of the body are calculated, if we may so, for the natural condition of man. The manufactu is sometimes removed from that condition; and our vention must be taxed, not only to maintain the puri of the atmosphere in which he works, in a chemic sense, but to arrest, or convey away, the small porti of material which may be thrown off by the operation the flax-dresser, for example, in heckling, or of cutler, whose occupation it is to grind the steel afte instrument is forged, or of the stone-cutter, &c., a to prevent those particles being inhaled. The leng the passages which lead to the lungs, the sensibili muscular apparatus bestowed upon them, and the r secretions thrown into them, are the natural me which foreign matter is arrested and thrown ou in these artificial conditions of men, insoluble are continually floating in the atmosphere whi breathe; these are drawn in and lodge in the lu irritate to disease.

The reader will find that the following extr

upon the actions of the windpipe, illustrates the
subject.*
e read that the trachea is formed of imperfect
of cartilages joined by membranes, and that it is
the back part for these reasons: that it may be
and free tube for respiring the air; that it may
nodate itself to the motions of the head and neck;
t it may yield in the act of swallowing to the
led œsophagus, and permit the morsel to descend.
perfectly correct: but there is a grand omission.
all admit that a copious secretion is poured into
ssage, it is not shown how the mucus is thrown off.
here is a fine and very regular layer of muscular
n the back part of the trachea, exterior to the
s coat, and which runs from the extremities of the
ges of one side to those of the other. This trans-
muscle is beautifully distinct in the horse.
hen a portion of the trachea is taken out, and
thing is dissected off but this muscle, the cartilages
eserved in their natural state, but the moment that
scular fibres are cut across the cartilages fly open.
muscle, then, is opposed to the elasticity of the
ges of the trachea. By its action it diminishes the
of the tube, and by its relaxation the canal widens
t the operation of an opponent muscle.
he whole extent of the air-passages opens or ex-
during inspiration, and then the trachea is also
ree; but in expiration, and especially in forcible
oration and coughing, the trachea is diminished in
The effect of this simple expedient is to free
ssage of the accumulated secretion, which, without
ould be drawn in and gravitate towards the lungs.
the air is inspired, the trachea is wide, and the
is not urged downwards. When the air is ex-
, the transverse muscle is in action, the calibre of
be is diminished, the mucus occupies a larger pro-
n of the canal, the air is sent forth with a greater
s than that with which it was inhaled, and the

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* '*Philosophical Transactions.*'

consequence is a gradual tendency of the spata towards
the top of the trachea. In the larynx the same princip
holds; for as the opening of the glottis enlarges in in
spiration, and is straitened in expiration, the sen
glottis, by inducing coughing, gets rid of its encu
brance. Without this change in the calibre of t
trachea, the secretions could not reach the upper end
the passage, but would fall back upon the lungs.

"Experiments have been formerly made by M. Fa
which, although no such view as I now present w
then in contemplation, prove how the action of the t
verse muscle tends to expel foreign bodies. The trach
of a large dog being opened, it was attempted to th
different substances into it during inspiration, but th
were always sent out with impetus, and could not
retained. Why the dog could not be thus suffocated i
apparent: the tube is furnished with this most saluta
provision to secure the ready expulsion of all bodi
accidentally inhaled—the air passes inwards by the si
of the foreign body, but, in its passage outwards, th
circumstances are changed by the diminished calibre
the canal, and the body, like a pellet filling up a tub
must be expelled by the breath."

We have, perhaps, pushed the inquiry far enough
and yet the interest might be increased by observing th
manner in which the textures of the ribs are accom
modated to variations in the mode of respiration, or t
the necessity of the animal expressing the air from th
lungs in diving. We have seen how the thorax is e
panded in birds to the whole extent of the body, f
obvious reasons; and the counterpart of that is present
where the animal, instead of being buoyant in the atm
phere, has to dive into the water and crawl at th
bottom—not at great depths, but yet under water, i
shallow pools and marshy places. The frog has no ri
and its mode of respiration shows a complete chan
from that of animals which breathe with a diaphrag
It has the power of compressing its body, and expelli
the air from the lungs; and were it not for this, th
animal would remain on the surface of the water as wh

ɜl boys blow them up with a straw. The crocodile other saurian reptiles have their ribs accommodated s to produce a similar effect, and for a similar pur- ɜ. Instead of the arched form of the ribs, which we ɜ described as capable of a slight change of figure ', they have ribs composed of distinct pieces, and ted in such a manner as to enable them to compress chest into a smaller volume.

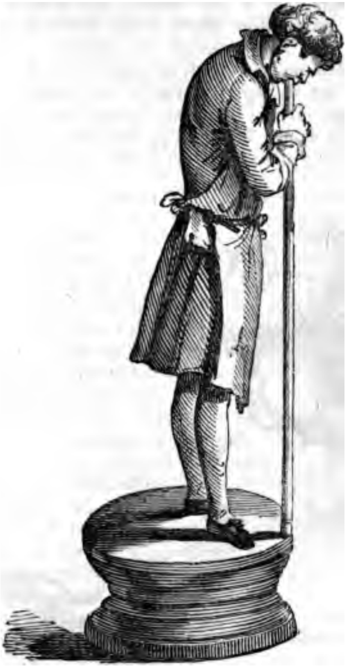
Ve have a sort of exposition of the uses, if not the ɜssity, of respiration to the voice, in observing by t substitutes sound is produced, for example, in in- s, which do not breathe by lungs. And indeed the a consideration suggests the inquiry as to the means which the atmosphere is agitated, in the same class of nals, in subservience to the sense of smelling.

VII

THE SUBJECT CONTINUED WITH REFERENCE TO TH CAPACITY OF THE CHEST, AND ITS CONDITION DURIN BODILY EXERTION.

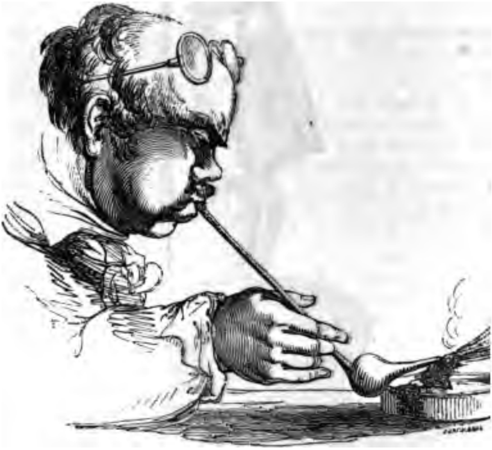
We must approach this part of our subject by the con- sideration of that law of fluids which appears, at first, s contradictory as to be called the "hydrostatic paradox."

Suppose a machine formed of two boards of equ diameter, and joined together by leather nailed to their margins like a pair of bellows: a hole is made in th upper board into which is inserted a tube. Now, if person mount upon this apparatus when it is filled wi water, and blow into the tube, he can raise the upp board, carrying himself upwards by the force of his ow breath—indeed, by the power of his cheeks alone. I is on the same principle that, when a forcing pump is l into a closed reservoir of water, it produces surprisi effects. The piston of the hydraulic press being loade with a weight of one pound, the same degree of press will be transmitted to every part of the surface of t reservoir that is given to the bottom of the tube, and t power of raising the upper lid will be multiplied in t proportion that its surface is larger than the diameter the tube. Or, to state it conversely: suppose we had raise the column of water in the tube by compressing reservoir, it would require the weight of a pound on ev portion of the superficies of the reservoir equal in ext to the base of the piston, before the water could be rai in the tube. If the apparatus which we have descri were full of air instead of water, we should witne similar effect; for all fluids, whether elastic or not, equally in all directions; and this is the law on wh the phenomenon depends. If we blow into the nozzle



mon pair of bellows, it is surprising what a weight
ks we can heave up if laid upon its board.
lerstanding, then, that the power of the hydraulic
in raising the lid, depends on the size of the re-
r, and its relation to the tube; and again, that in
ng the fluid up through the tube, the pressure upon
les of the reservoir must be the greater the larger
vity, we can conceive how a glass-blower propels
into his blow-pipe with great ease, if he blows

with the contraction of the cheeks, the *smaller* but with an exhausting effort, if he *blows by th* pression of the larger cavity, the *chest*. Dr. made a calculation, the result of which was, that, i pelling the air through a tube of the same *calib* weight of four pounds operating upon a cavity *of the* of the mouth would be equal to the weight of sev pounds pressing upon a cavity of the dimensions of chest.*



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* The action of one who uses the blow-pipe is rat curious. The mouth is distended with air, and the pass at the back of the mouth closed; the man breathes thro the nostrils, but, from time to time, admits a portion of into the mouth in expiration. The pressure into the bl pipe is from the distension and consequent elasticity of cheeks, occasionally assisted by the buccinator muscle, trumpeter's muscle, so called because it compresses the tended cheeks. In this way the stream of air through *blow-pipe* is kept up uninterruptedly, whilst the *breathes* freely through his nostrils.

Let us see how beautifully this hydraulic principle is introduced to give strength in the common actions of the body. We have remarked that the extension of the superficies of the thorax is necessary to the powerful action of the muscles which lie upon it; and these are the muscles of the arms. We must all have observed, too, that in preparation for a great effort, we draw the breath and expand the chest. The start into exertion, and of surprise, in man and animals, is this instinctive act. But unless there were some other means of preserving the lungs distended, the action of those muscles which should be thrown upon the arms would be wasted in keeping the chest expanded. It is here, then, that the principle which we have noticed is brought into play. The chink of the glottis, which the reader has already understood to be the top of that tube which descends into the lungs, is closed by a muscle not weighing a thousandth part of the muscles which clothe the chest; and this little muscle controls them all. A sailor leaning his breast over a yard-arm, and exerting every muscle on the rigging, gives a direction to the whole muscular system, and applies the muscles of respiration to the motions of the trunk and arms. through the influence of this small muscle, that is not capable of raising a thousandth part of the weight of his body: because this little muscle operates upon the chink of the glottis, and is capable of opposing the whole combined power of all the muscles of expiration. It closes the tube just in the same way that the man standing on the hydraulic bellows can with his lips support his whole weight. Thus it is that the muscles which would else be engaged in dilating the chest are permitted to give their power to the motions of the arms.

Some cruel experiments have been made, and, for whatever intended, they illustrate the necessity of closing the top of the windpipe during exertion. The windpipe of a dog was opened, which produced no defect until the animal was solicited by his master to leap across a ditch, when it fell into the water in the act of leaping because the muscles which should have given force t fore-legs lost their power by the sudden sinking of chest. The experiment is sufficiently repugnant to feelings; and I need not offend the reader by gi instances in further illustration from what somet takes place in man.

VIII.

LATION OF THE BODIES OF BIRDS TO THE ATMOSPHERE.

object noticed in Chap. xvii. is the wing of
d this is given as an instance of *the relation of
body to the elements by which it is surrounded.*
t our readers' attention to the philosophy of
t. And let us not be contented with admiring
re of the feather, or the adaptation of the
he wing to their office, but let us go deeper
quiry: it is a subject which will reward us.
ke it for granted that a creature is to live by
e of the same functions with the races of
r quadrupeds, as digestion, assimilation, re-
c.; but that it must rise in the air and seek
ong flights. What are the circumstances
this new condition? Is it not obvious that
nust be specifically lighter or more buoyant
here?—that instead of its muscular system
and directed to the movement of four ex-
ust have its strength principally directed
that it may extend them and be able to
upon them? Let us then see how this
l, and how the original animal economy
ith an entirely new machinery of motion.
ect will be attained by enlarging the
l, without increasing the weight in any-
ame proportion—and one very obvious
nd in extending the trachea or wind-
ing the tame and wild swan, the most
vill detect the provision for flight in
conformation of the windpipe which

This sketch from the male crane will illust
mean. The light and hollow air-tube fi
the interior of the bone, by which the su
tended for the attachment of the muscles
and thus two objects are attained through i

In attempting to explain the reason of su
from the common forms of parts, we are
into the same mistakes as we find occasio
mentators on the Sacred Volume. Wer
for the varieties of the organs of voice, we
start to the conclusion that we had found
body a complex instrument resembling a
Siberian hunting-horn; but by further inqu
discover that some of those birds that h
complex and varied windpipe have no cry

But there is a still more curious provisi
tension and magnitude of the body of a
dently of weight. In birds the air does
into their lungs, but through them, so as
of air-cells, composed of fine membranes wh
woven with all the viscera. The heart is s
such a cell. Two great cells are attached
and in the same manner are all the viscera

men interspersed with air-cells, and these all con
cate. The air thus admitted into the interior of the
extends even into the bones. Naturalists have mi
the end of this structure when they have represe
as a developement of the respiratory organs. It
to make the function of respiration more perfe
the air enters so extensively into the body; as a
of which, the air in the bones of the head is su
through the nasal cavities and Eustachian tubes
pendently of the lungs altogether.*

Mr. Hunter has shown us, that in many bir
internal air-cells communicate with the exterior c
membrane, especially in the neck and axilla,
marks an analogy with the air-cells under the
the bat. Winged insects, too, have their bodi
tended by air-cells communicating with their resp
apparatus. These facts sufficiently evince the ob
Nature in this extension of the air-cells: that it
for the purpose of breathing, but for enlargir
volume of the body without increasing the weight

We must observe the very peculiar mechanism
bird's respiration. The breastbone or *sternum*,
the whole length of the animal's body, and the
central spine of that bone called the *keel*, rises f
so as to give lodgment and attachment to the
muscles of the wings. It will be easily understoo
naturalists distinguish birds of passage by the
the keel (crista), since its greater prominence i
strength of wing for long-continued flight. Und
breast-bone, and between it and the back-bone, w
ceive the space occupied by air-cells. The lun
lie behind; and by the motion of the bone A,
great bellows, the air is drawn through the lung
through the windpipe, C, into the cells D, E; a
effectually oxygenating the blood in the lungs, a
renewing the air within the recesses of the body.

The next thing remarkable is in the vertebræ o
for the backbone is in its constitution unlike t

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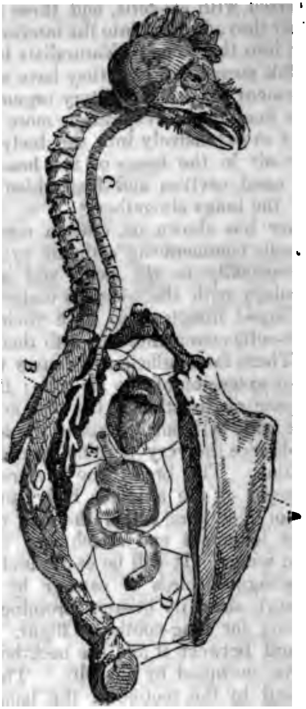
* Mr. Hunter's 'Animal Economy.'



man or quadrupeds. The back is firm and the
extremity loose and moveable. The first is obv
ended to give a fixed origin to the muscles
r, and the second to afford motion to the tail.
he wings they raise or propel themselves, a
ail th heir flight. We need hard
the centre of gravity co

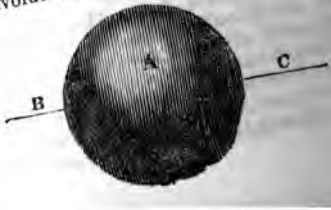
mals; in birds the centre is between the wings.

If our reader has followed us in these details, he will acknowledge that there cannot be a more curious instance of a change and adaptation of the whole system of the living body to the external elements, than is to be found in the system of birds.

IX.

M OF THE EGG, OR REVOLVING OF THE YOLK.

stration used in the Preliminary Discourse,
anner in which the cicatricula, containing the
thin the egg, is presented to the breast of the
uires the following diagrams in explanation.
n we hold an egg steady, and chip it at the
part, we find the yolk close to the shell; and on
per surface a pale vesicle, the cicatricula, which
ns the embryo chick. When the hen sits, the
f her body developes the action of the living prin-
in the embryo, and on the second and third day a
zone of blood-vessels appears; these vessels run
rds the embryo, and carry nourishment to it; and
by day we may watch its sensible growth. From
delicacy of this action we may perceive how neces-
y it is that the embryo at this early period should be
ose to the breast of the hen, and not at the cold bot-
om of the nest. We shall now see how it is accom-
lished. The yolk is a globe of nutritious matter, and
he little vesicle with the embryo is involved in the sur-
rounding membrane, and consequently, as we have said
is at the surface of the globe. If this globe had the
axis of its revolution thus, in the centre, it would a



This beauti
publication w
ier, and t

A A, is th
treddles c
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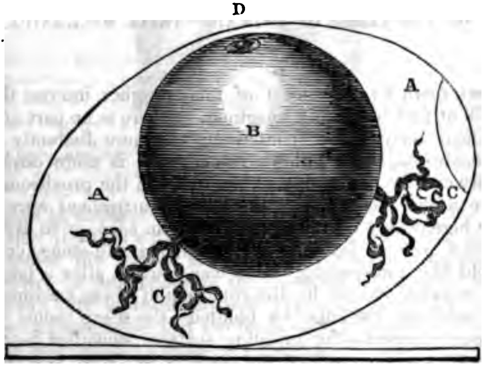
move with the change of the position of the egg. But the axis being below the centre, it must turn round with every change in the position of the egg, whether the globe be heavier or lighter than the surrounding white: were it heavier, it would revolve so as to bring the embryo to the lower part of the shell—were it lighter, to the upper part of the shell. It is lighter, and the matter stands thus:



[This beautiful apparatus has not been understood; and in the last publication which touches on the subject the yolk is supposed to be heavier, and to hang upon the chalazæ.]

A A, is the white of the egg; B, the yolk; C C, the treddles or chalazes; that tough matter which we find in eating an egg little boiled. Each of these bodies is connected with the white, and attached at a point to the yolk. The yolk being as it were anchored at these two points, and the attachments being below the centre, and the yolk being lighter than the surrounding white, it revolves like a buoy, and the cicatricula containing the embryo D is thus kept always uppermost.

If "the chicken roosting on its perch be related to the mass of the globe and the earth itself," as our author has affirmed, what may we say of the revolution going on within the egg?

X.

OF THE TEETH OF ANIMALS—THEIR MECHANICAL PROVISIONS.

The teeth form a subject of much higher interest than will at first be readily imagined. There is no part of an animal body where 'contrivance' is more distinctly demonstrated, or in which a resemblance is more obvious between the mechanism of engines and the provisions in the animal mechanism. Suppose an instrument were to be ingeniously contrived to cut like an adze, or to divide like a pair of shears, or to grind like a mill-stone, or to hold like a mousetrap,* or to tear,—what, after a period of working, would be the condition of these machines? Would not the edge be blunted—the sharp points become rounded—the grinding surfaces smoothed?—and would not the teeth of the machine be driven deep into the sockets, and so render it wholly useless? But nothing of this kind takes place in the teeth of animals. They are perfect for their purpose, and, if duly exercised, last the natural term of life, however the period of natural decay may vary in different animals.

To commence with the manner in which the teeth resist pressure into the jaw. If we look to the teeth of the lion, we find their roots conical and socketed, as if a nail were driven in; and so it is in the remarkably strong teeth of the hyæna.

Now these animals have powerful muscles, closing the jaws with a force to break the strongest bone. How is it, then, that the teeth are never pressed deeper into the jaw? For undoubtedly this would be the effect in an

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* As in the gullet of fishes.

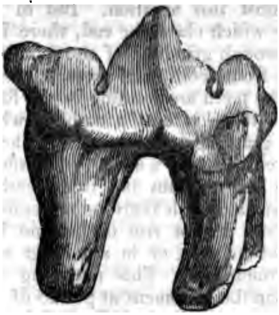
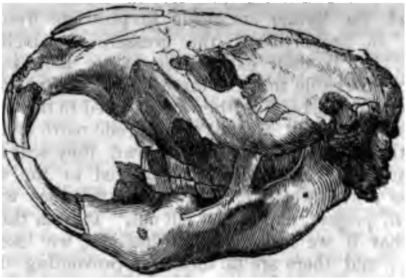


figure represents the back tooth of the Tiger's jaw, which closes like the blade of scissars.]

ne so constructed by man's ingenuity. The reason
hat there is a living property in the teeth and jaw,
vhich the former are made to protrude from their
ets, in proportion to the pressure to which their
vns, that is, their exposed parts, are subjected. It
ery remarkable that the teeth during their period of
vth, notwithstanding they are exposed to the pressure
nastication, will ascend or protrude more and more
of the jaw; and when fully grown, they will remain
ionary and on a level, if subjected to the natural
sure of mastication; but without this they will rise
high, project, and at last fall out. It is on this prin-
e, that if we lose teeth in one jaw, we lose them
oth; and there are no means of preventing the loss
hese, but by such mechanical substitutes as shall re-
e them to their due exercise. And yet Nature
lifies the law with perfect ease, and, as it were, at
. Let us take an example:

'he front teeth of the horse are called "nippers;"
r meet, and crop the herbage. As the horse is a
etable feeder, he must grind with his back teeth, and
ng this act the front teeth must participate in the
ding motion. We shall presently see how they

protected against this attrition. But in the rumi animals, those which chew the cud, there is a nece for a more thorough grinding of the food, whilst at same time the front teeth must preserve their edge. this purpose the teeth are wanting in the fore part o upper jaw, and there is only a cushion, which emb and holds the grass against the edge of the lower te so that it is cut, as with a sickle, by a smart twitc motion of the head. Thus the front teeth underg attrition. Now, although there be no teeth in the u jaw, those below do not rise or become loose, as certainly would in man, or in any other animal, no the class of ruminants. This reasoning will be m satisfactory than the statement at p. 225 of vol. ii. objects are here attained; first, that the cutting teet preserved sharp; and, in the second place, these t differ in their condition from ours, since they do not in consequence of wanting opponents.



[The figure represents the skull of the Beaver, to show the na their cutting teeth.]

In the class of rodentia or gnawers, the front t must cut with a sharp edge. We know how this is trived in the tool of the carpenter; and we know that he must from time to time apply his chisel to grindstone. The front teeth of the beaver, the pc ne, and the rat, are sharp and yet not blunted by one of the tooth is the densest possible, consisten the material; but were the whole tooth of the same rial, it would be ground down uniformly, and the nal form of the instrument would be lost. Accord-, a different substance, the enamel, which yields slowly to attrition than the bone of the tooth, is, were, let in on the anterior surface of the tooth. consequence is, that the enamel stands up sharp and sed, so as to protect the bone of the tooth, and to the surface which is worn down a certain shape, hat original shape suited to cut like an adze. The ion and the arrangement of the material of the tooth r correspond, that the cutting form is preserved, ever much the surface may be worn down.

ow, a tooth cannot grow; and as we have seen that wasted by friction, how is the cutting edge to retain lace? When the steel plate of the carpenter's plane rced in by repeated taps with his hammer, he pro- the sharp edge, and when it is elevated above the in a just degree, he fixes it there by a smart blow ie wedge; but the cutting edge of the chisel-like rs of the rodentia is still more finely adjusted.

the first place the tooth is very long, extending the length of the jaw, and it is of a curve not easily ed, not partaking of any section of a cone; still adapted, that the cutting edge meets its opponent nd, although incessantly wasted, it is accommo- the growing jaw. We have said that a tooth grow. It does not grow like a bone, but some- ditions are given to it at the root; such is the this class of animals: the tooth of the gnawer is hed on along the jaw, owing to the growth ace at its root and in its proper curve; so that g edge is protruded in proportion as it is wasted cess of attrition and sharpening. This is a rowth which takes place in no other animal's h.

now observe how the grinding surface of the herbivorous animal is composed. It must be egular, so as to catch the grain. A smooth millstone, for example, would not bruise the gr meal. The burr-stone, accordingly, is sought nether millstone. This stone contains small port feldspar, imbedded in a softer material; and thus ever the surface may be ground down, the hard terial, by yielding less easily to friction than the projects above the general level, and preserves a ness of the surface even whilst it is yielding. It is so with the tooth of a graminivorous animal. It i posed of alternate layers of the hardest bone, or ra ivory, and a denser material still, the enamel. Th sequence of this inequality in the composition i notwithstanding the surface of the tooth is worn the roughness is preserved.

[The figure represents the molar tooth of the Horse, and exh roughness of its upper surface, and the depth of the body of the *the jaw* commensurate to the pressure it bears.]

There is something curious, too, in this irregular
owing that it is as far as possible from accident. T
es of enamel which stand up differ in their arran
ent according to the motion to be given to the jaw.
e horse and cow these ridges run parallel with the ja
d consequently lie across the direction of the motio
chewing, which is from side to side. In the rodentia
the other hand, the line of the enamel of the grindin
th runs transversely to the jaw; and in masticatio
e jaw is drawn backwards and forwards, not laterally.
is original composition of a grinding tooth is, there-
e, superior to the best millstone. The roughness,
ich is so like a thing accidental, is found to proceed
m an arrangement in accordance with the motion of
astication. It might, in like manner, be easily demon-
ated that there exists a similar accordance with the
m of the jaw and with its articulation; but the in-
nces already given of adaptation may suffice.

Before leaving the subject of the provisions against
e wasting of the teeth by friction, there are one or two
cumstances of a very interesting nature to be noticed.
e elephant is a graminivorous animal, and requires to
d its food very thoroughly. What then must be the
ision in the grinding tooth of this animal to with-
d the power of its jaws? We find the teeth, in fact,
ed of three substances, and, we may say, of a struc-
superior to the teeth of the lesser graminivorous
ls, of course admirably suited to resist the action of
ing. But there is a circumstance peculiar here.
ugh the matter of the tooth once formed does not
e, an alteration in the position of the tooth in the
ay produce a similar result. When the great
g tooth of the elephant appears first above the
e anterior corner only projects; but as that be-
vorn down, the tooth, by revolving on its centre,
in slow, but regular succession, more and more
urface, guarded with new plates of enamel, until
last worn to the roots. Here, then, we have a
extraordinary provision against attrition in the
an animal which lives to a great age. The

structure of the tooth itself has a very *large proporti* of enamel, in dense and regular ridges; but as *if th* material of the teeth could be brought to no greater *per*fection to withstand the chewing, it is "contrived," for we have licence for such language in our author, that the tooth itself shall undergo a revolution, not being simply elevated from the jaw, but turning on an axis.

There are other modes in which Nature counteracts the wear and tear of the engine; and the provision which we have now to mention supplies not only a substitution of more perfect teeth for those that are injured, but teeth of a size as well as form suited to the growing jaw. In the crocodile, for example, the teeth are conical and sharp; but if not worn, they must be torn away, and there is a necessity for a succession. It is thus provided: under the exposed tooth there is another one lodged, of the same shape; and under that a second and a third. Each tooth, as it is deeper in the jaw, is larger in its base, and longer and stronger. So it happens, that when a tooth is torn off, it is only the uncapping of a sharper and a stronger tooth.

The same end is attained differently in other creatures. In the rays, such as the skate, and in the shark, the succession of the teeth is still more curiously managed. The jaws resemble a part of a cylinder, studded with many rows of teeth. The teeth of the outermost row being in use, are liable to be torn off or worn down; when this occurs, their places are supplied by a revolving of the solid base on which the teeth are studded, and the posterior ranges advance in succession. Here, then, we not only find sharp and cutting teeth, like those of a saw, but, corresponding with the boldness and voracity of the animal, we see a provision for their rapid renewal.

It is interesting to see how the same class of parts may be modified, and yet retain their original destination of supplying the stomach with food, and preparing it for digestion. What teeth could we suppose suited for the whale? Now the largest species of whale feed upon a small molluscous animal which abounds in the northern ocean. The teeth are here, we may say, converted into

ce like horn, with which we are familiar under
e of whalebone. They consist of plates of this
ne attached to the upper jaw, and placed in rows
uter margins. Their loose edges terminate in a
s if the plates were split and teased into shreds;
is undoubtedly for the purpose of retaining the
, while the water is drained through their in-

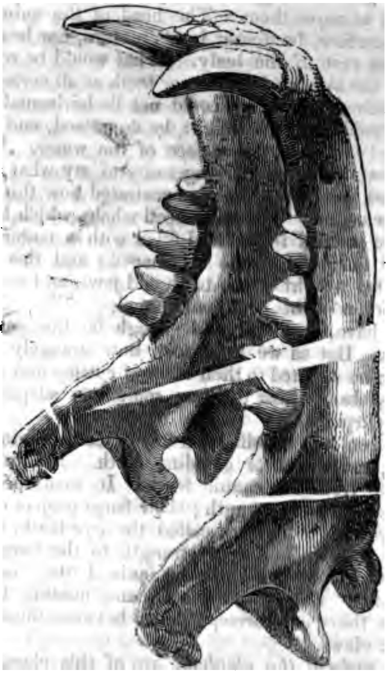
s curious apparatus there is, of course, no neces-
reat strength in the jaw, nor for very powerful
to move them. The head of the animal needs
efore, be denser in its texture, nor less buoyant
rest of the body. What would be required if
e species had jaws or teeth at all corresponding
r size? They could not lie horizontally; their
ld, from its weight, be depressed, and their tail
towards the surface of the water. We need
ever, strain our ingenuity to say what would be
for Nature has demonstrated how this defect is
edied. The spermaceti whale, which has teeth,
avities in its head filled with a material much
han water, the spermaceti; and this counter-
e weight of the teeth and jaws, and restores the
m of this cetaceous animal.

ve, perhaps, said enough on this part of our
But as we have seen how strangely the teeth
e adapted to their office of cutting and grinding,
bserve that they are sometimes adapted to dif-
rposes.

mmon classification of the teeth is into incisors,
d molar or grinding teeth. Let us take our
from the canine teeth. In man they are of
th and strength; their fangs project deep into
jaw; they are called the eye-teeth, and they
ustain and give strength to the range of the
In the carnivorous animal they are called
;" they are for tearing and holding, for which
ere is a correspondence between them and the
aws.

sks of the elephant are of this class, and be-

tween these the tender trunk is protected. In the l
the canine teeth project, and become powerful inst
ments, not for biting, or holding, or tearing, but
rending, or rather cutting; that is, the whole forc
the animal in its rush is directed to give effect to
tusk. So little are the tusks calculated for biting, t
the tusk of the lower jaw closes in upon that of the up
jaw, so as to support its base, and to give it stren
commensurate to the power and impetus of the ani
But we must not suppose that the tusks are solely for



[The figure of the lower jaw of the Tiger] purpose of offence. The strength and the power of the neck of the boar is mainly for the purpose of ploughing up the earth and rooting up herbs by means of its tusks.

In some animals, as the babyroussa, this tooth rises and twists, so as to make it at first sight appear useless. Certainly the tusk is neither for holding, tearing, nor masticating; yet it is not useless. This animal escapes from his enemies by the facility with which he rushes through the brushwood; and these teeth are curiously calculated to bear aside the branches and to protect the eyes.

In other animals, as the walrus, the canine teeth of the upper jaw become tusks, but project in an opposite direction to those of the elephant. They enable the animal to raise itself out of the water, by holding on upon the rock or iceberg, as the parrot steadies himself by the bill.

XI.

THE SUBJECT PURSUED WITH REFERENCE TO THE FORMATION AND GROWTH OF TEETH.

EEING how admirably these instruments have bee
lapted to their several uses, the reader must be curiou
know how they are produced—how they are manufac
red with so fine a "prospective contrivance." Thre
fferent substances are exposed on making the section
tooth; viz. ivory, or the bone of the tooth—the enam
hich is very hard, and breaks with a vitreous fracture—
d a substance differing in some respects from both, an
hich English anatomists have called crusta petrosa, an
uvier cement. These three substances are not form
every tooth. Some teeth consist entirely of the bo
ivory, as those of the porpoise and bottle-nosed wha
man, and in the carnivorous animals, the bone is c
red with enamel, and in the graminivorous and rum
nt animals, all three substances are found.

In the chapter on bone, it has been shown that i
xture must be loose to admit blood-vessels; for bone i
urished and undergoes changes through the influen
the circulating blood in it. But the almost sto
nsity of the teeth does not admit of circulation with
em; yet they possess life, and through that princip
e in union with the gum and jaw. A dead tooth, how
er pure and perfect, when thrust into the socket of th
, remains there no longer than would a peg of wo
of metal. It causes inflammation and pain, and
own out.

It would be a difficult question for those who consid life to be the result of organization to solve, how a principle of life should exist for a term of years, giving rise to a sympathy and union with the jaw, in a part like the bone of a tooth, which has neither what they call organization nor any circulation of blood in it. Here we have one of those inscrutable qualities of life which makes physiology a science distinct from all others; and it is an example of there being adaptations far more admirable than merely mechanical appliances.

But we were about to show how the different portions of a tooth are formed. In the jaw of the young animal a sac is discovered, which contains the rudiments of the tooth. On opening the sac, we think we see the tooth, but it is only a body of the form of the crown of the tooth, and is soft to the touch. This is called the *pulp* of the tooth; although pale at first, at a stated period it becomes full of blood, and then the bone of the tooth begins to be formed; and now, on touching it, we can lift from it a delicate shell, which is at once of the form of the pulp, and of the perfect tooth. The process thus begun is completed by the secretion of successive strata from the surface of the pulp, until the bone of the tooth, which was at first a mere scale, becomes a dense body, with a small cavity and tube leading to it; and the pulp, which was of the size and shape of the tooth, shrinks to a mere shred, containing a nerve and vessels.

Thus the original use of the pulp is changed: but it remains, serving an important purpose; for by sustaining a sensible nerve within the tooth, it extends a degree of protection to it. The teeth are sensible to what we masticate; they are sensible to the smallest particle of sand, and so are they to the degrees of heat. This sensibility is necessary to their protection, and to the continuance of their vitality, yet the sensibility is not in the substance of the tooth, but in the nerve within; and the density of texture of the tooth becomes a medium through which both mechanical vibration and heat are readily communicated to the nerve.

We have seen how the bone of the tooth is secreted by the *pulp*. *The enamel is* formed differently. The sac, which covers the whole pulp and rudiments of the tooth has a fine organization, as displayed by the art of the anatomist, and its inner surface throws out a fluid which, falling on the surface of the bone of the tooth (already formed by the pulp), there concretes, or undergoes a species of crystallization, and hardens into enamel.

The difference between the bone and enamel of a tooth, that is, between what is formed by the pulp and by the sac, is shown by a very simple process. When a tooth is immersed in diluted nitric or in muriatic acid, the enamel is dissolved with effervescence, and is completely carried away; but when the earth of the bony part is dissolved, it leaves behind it a cartilaginous matter, which constituted a part of the bone of the tooth. In its chemical composition the bone of the tooth resembles the bone of the skeleton, though not strictly and anatomically, as it wants the vascularity of true bone; it is therefore, with more propriety, called ivory.

We have still to explain how the compound teeth of the vegetable feeders are formed. Now, if we comprehend the means employed in the simple tooth, we shall have little difficulty in understanding this. The pulp is divided, and consists of parallel layers joined below, but free above, and with considerable interstices. These divisions or processes of the pulp secrete the ivory upon their surfaces, by which, of course, plates of this dense material are formed on each side of the soft processes or tongues of the pulp. There will therefore be double the number of plates of bone that there are processes of the pulp.

Each plate of bone must be covered or invested with enamel. This is effected by folds or projecting processes of the capsule or sac, which, hanging from above, intervene between the plates of bone, and there perform their peculiar secretion, depositing the enamel. But it would appear that these processes, becoming at length tightly embraced by the plates of enamel which they have themselves secreted, throw out a less perfect material, as it were; this is called the *crusta petrosa* or cement. When the tooth thus formed rises above the gum, and when at-

ı wears down a part of it, the interstices caused by
asted processes of the septa of the sac are exposed,
ıe food is crammed down into these crevices, and
on making a section of the tooth we may discover
ıbstances, ivory, enamel, crusta petrosa, and foreign
-, in alternate layers.

w, contemplating the slow formation of the teeth
yet deep in the jaw,—their curious mode of growth,
ed to the form of the jaw,—the articulation of the
ith the head,—the position and powers of the mus-
hat are to move the jaw, with the means to be
yed by the animal in gathering, masticating, and
ing its food,—we can desire no more absolute proof
spective contrivance and design. Were we to
urther, we have only to compare these mechanical
nces with the instincts and propensities of the
ls.

. . . .

ere is but one thing more worthy of attention in the
than their mechanism, we mean their vital proper-
Is it not a wonderful thing to see the jaw of the
with a ridge upon its gums, harmless to the nipple;
hen at the time when the powers of digestion vary,
ecome suited for stronger food, to find sharp teeth
a range of them having been provided, which when
developed are in exact accordance with the size and
of the jaw of the child? Can any one tell us how
teeth should waste at an appointed time, to give
to others of stronger form and of larger dimensions
rming to the adult jaw-bone? The phosphate, car-
e, and fluate of lime, do not differ in these milk-
, or deciduous teeth, and in the adult teeth; yet, by
ret process of decay, the first fall out in the period
ldhood, and the second last a long lifetime.

XII.

OF THE MOUTH.

Our author has said that everything in the structure o the mouth is mechanical, and he has given a very attra ive view of the varieties of the mechanism in the mou and bills of animals. But so far from exhausting the s ject, he has left some of the most interesting particul untouched. In man, the mouth is not flat because he h hands, but because it is a part of that apparatus, which the most curious and important of all the bodily st tures,—the instrument of speech. In that light we sh presently take it up separately, not doubting that it w reward the reader's attention.

Let us, in the meantime, consider some of the common properties of the mouth; and first, of the most obvio parts, the lips. Nothing serves better to make us appreciate the blessings we enjoy, than examining the organization of a part which, from its familiarity, and the absolute perfection of its action, we neglect or think meanly of. The lips receive the food, and aid in mastication; they are a principal part of the organ of speech; they are expressive of emotion; they are the most acutely sensible to touch. But all this never moves our surprise or admiration.

If we know anything of muscularity, we must presume that there is a concourse of fine muscles converging to the lips and surrounding them. But what gives the lips their sensibility? This was a question early suggested to me in my investigations on the nerves; when experiment showed that one nerve went to the lips for sensation, and another for motion. The vermilion surfaces of the lips *possess their* exquisite sensibility through minute and de-ate villi, into which the extremities of the sensitive rve are distributed: and these, being covered only by uticle the most thin and transparent, afford the ready trument of touch. We see how the child uses the s, as giving him his first information of the qualities of dies.

It is certainly an unexpected thing to find that two or- nizations totally distinct, combined in the lips, should necessary to the simplest act. If the nerve of motion cut and has lost its function, the animal puts its lips to e grains it feeds upon, but cannot gather them. If the rve of sensation be injured, the animal presses its lips the food, but wants the sensibility by which the mo- ns of the lips should be directed. These facts show at whilst sensibility and motion are distinct faculties and pend upon different nerves, they are necessarily com- ned for so simple an act as taking the food into the uth. We thus daily see that in paralysis, sometimes e property is lost, sometimes another; a circumstance st important to the physician.

As connected with our present subject, it is a strange ing to see that, whilst a person may have every capa- y for motion in the lips and tongue, he will have the rsel remaining in the mouth without knowing it. The st instance I found of a defect in the lips exactly similar that produced by cutting the nerve of sensation on one e of the face, was in a gentleman who, being under the nds of his dentist, had the nerve of sensation hurt by pulling of a tooth: and having a glass of water given him, remarked that the glass was a broken one: the t being, that the portion of the tumbler in contact with e half of his lips was not felt at all, which gave him the ne sensation as if a bit of the glass had been broken ay.

We might show, in the lower creatures, an infinite riety in the forms of the mouth; but even in the mam- lia, we may perceive that the lips are projected, and ve a power almost like that of the hand. The horse s great power in his lips. The camel, the elk, but ore especially the rhinoceros, have a still greater mobi-

lity, and the latter has a very fine sensibility in the
shaped extension of its upper lip: the snout of the
and the trunk of the elephant belong to the lips,
than to the nostrils. We have the least equivocal
of this, in their supply of nerves, which are only
largement or prolongation of those nerves which i
go to the lips. Nay, we may state a fact, perhaps
pected to the reader, that the whiskers of animals
cat tribe have entering into their roots branches
same nerve which gives sensibility to the lips; a
palpa and tentacula in the lower classes of animals
crustacea and insects, however different these orga
appear, are known to belong to this order of parts,
same proofs, their supply of nerves.

We might be tempted here to speak of the
birds, had they not already attracted the attentio
author. We shall, therefore, rather fortify his
sions by attention to the structure of the tongue
human tongue is, no doubt, the most admirable o
organs. We might have very obvious proofs of i
and adaptation in the long rough tongue of the o
the still more curious and active tongue of the cam
or in the tongue of the insectivorous animals, th
the chameleon, and ant-eater, or in the variety of
instruments, darts or saws, sheathed in the bills of
vorous birds. But we ourselves have an organ, l
apparently simple, finer than all these. The
tongue, containing muscular fibres in every possibl
tion, and round, soft, and mobile, is less admirab
organ of mastication, of taste, or touch, than as th
of speech, modulating with every possible vari
sounds issuing from the windpipe. On the upper
of what is termed the dorsum of the tongue, th
rough papillæ which in some measure correspo
what we see in animals: they are subservient to t
Some of them have a mushroom-like top, and a st
jecting from the bottom of a little hollow, and t
sapid particles of the food lodge, and prolong the
ment of the palate. But in the organization of the
there is one minute point of structure more curio

rest. When the papillæ are examined with a ing glass, there are seen certain small bodies, con- ›f a grey sheath, within which there is a little red ınd this point is capable of erection, thus project- becoming the organ of taste. It is so erected ıe morsel is in the mouth, or when we are in the ıte anticipation of food. There are other more processes studding the surface of the tongue, and ntain the extremities of nerves which are sensible ı. It must surely, therefore, be considered an le thing to find so many faculties seated here, each appropriate organization, and each most curiously ɜd with other structures—that we should have the f mastication, of deglutition, of modulation of the ıe senses of taste and of touch, concentrated in ɪrently simple organ.

o speak of other relations, can there be any better design, than the effects of the excited sensibility :ongue? No sooner have these gustatory points s been excited, than there is poured out into the ıost abundantly, by four distinct tubes, the saliva, 1 * which facilitates mastication, and directly pre- e food for the action of the stomach. And how- l we might imagine such a supply of fluid to assist on, this is not all that is here done in preparation; ɜt the morsel is moved by tongue, and lips, and appropriate fluid is collecting in what appear to irregularities in the back part of the throat, but re, in truth, so many receptacles, that, pointing the stomach, give out their contents as the morsel

is one curious circumstance which we may

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presume that the fluid is chiefly useful in mastica- ıe glands are large, and the fluid most abundant in :hat chew the cud. In all, these glands are so dis- to receive gentle pressure from the motion of the hat, whilst their vascular apparatus is excited by bilities of the tongue, the fluid is urged from the the pressure of the jaw and muscles which move it. itself is neither acid nor alkaline.

notice before quitting this subject. Eating seems to be an act of the will, and attended with gratifi It is well known that the operation, or what is nearly the same, may go on within the stomach, with any outward sign at least of pleasure. The gizzard (wi which we are most familiar in fowls, though it be, in found in the vegetable feeders of the different class animals) is correctly enough described as an organ mastication, in which there is an incessant and alter action of opponent muscles, as in the motions of th iaws. In the stomach of the lobster we have not the muscles of mastication, but the teeth also: so that appears the function may be performed altogether ternally, and without the volition, and probably wit the sensations, that accompany the offices of the We mention this, as drawing the reader to compre that many organs may be in operation in the economy, without our consciousness.

Our author, with much propriety, from time to ti adverts to those changes in the organization which commodate the animal to new conditions. Now, terrestrial animals, the act of swallowing must be acco modated to the atmosphere; but if the animal lives water, and still breathes the air, the structure of t parts must be changed. The crocodile seizes its pre and descends into the water with it. Its power of scending does not, as in the fish, result from compress the air-bladder: but is owing, as we have shown, to provision in its ribs and lungs. Unless the crocod could expel the air from its lungs in a greater degr than the mammalia are capable of doing, it could crawl upon the bottom, nor retain its place there wi out continual exertion. There is an adaptation to t mode of destroying its prey, by carrying it under wa in the mouth, as well as in the thorax and lungs T crocodile has no lips; it lies on the shore basking wi *its mouth* open, and flies light upon and crawl into *mouth*. Against these the air tubes are protected, e lips and sensibility of the mouth, but by an ıtus which separates the mouth from the throat indpipe. This partition between the cavities is ary when the animal seizes its prey: for as it es under the water with open mouth, the air tube e protected against the ingress of the water. For urpose, there is a transverse ridge, arising from the of the bone of the tongue, which raises a duplica-f the membrane so as to form a septum across the art of the mouth; whilst the curtain of the soft hanging from above meets the margin of the lower n, and they form together a complete partition en the anterior and posterior cavities. Thus the l is enabled to hold its prey in the open mouth, ıt admitting the water to the air passages.

h these observations, we hope the reader will to peruse, with increased interest, the conclusions l stated by our author, vol. ii., p. 110.

XIII.

OF HUNGER AND THIRST.

FOR very sufficient reasons, we have preferred taki
illustrations of design from the mechanical struct
the body. We may now introduce some instances
the living properties, the propensities and appetites

Hunger and thirst are in truth senses, althoug
seat or organ is not easily ascertained. The wants
desires, and pain accompanying them resemble no
sensations. Like the senses, they are given us as
tors and safeguards, at the same time that, like
they are sources of gratification.

Hunger is defined to be a peculiar sensation
perienced in the stomach from a deficiency of
Such a definition does not greatly differ from the n
of those who referred the sense of hunger to the
chanical action of the surfaces of the stomach upon
other, or to a threatening of chemical action of the g
juice on the stomach itself. But an empty stomach
not cause hunger. On the contrary, the time whe
meal has passed the stomach is the best suited for
cise, and when there is the greatest alacrity of s
The beast of prey feeds at long intervals; the snak
other cold-blooded animals take food after interv
days or weeks. A horse, on the contrary, is a
feeding. His stomach, at most, contains about
gallons, yet throw before him a truss of tares or lu
and he will eat continually. The emptying o
stomach cannot therefore be the cause of hunger.

The natural appetite is a sensation related
general condition of the system, and not simply ref
to the state of the stomach; neither to its action,
emptiness, nor the acidity of its contents; nor

creature will a full stomach satisfy the desire of
Under the same impulse which makes us swallow,
inating animal draws the morsel from its own
.

er is well illustrated by thirst. Suppose we take
ition of thirst—that it is a sense of dryness and
tion in the back part of the mouth and fauces;
tening of these parts will not allay thirst after
tigue or during fever. In making a long speech,
's mouth is parched, and the dryness is merely
aking, it will be relieved by moistening, but if
from the feverish anxiety and excitement at-
a public exhibition, his thirst will not be so
. The question, as it regards thirst, was brought
monstration by the following circumstance. A
ving a wound low down in his throat, was tor-
th thirst; but no quantity of fluid passing through
th and gullet, and escaping by the wound, was
any degree to quench his thirst.

t, then, like hunger, has relation to the general
n of the animal system—to the necessity for
the circulation. For this reason, a man dying
ss of blood suffers under intolerable thirst. In
rst and hunger, the supply is obtained through
ification of an appetite; and as to these appe-
will be acknowledged that the pleasures result-
them far exceed the pains. They gently solicit
vants of the body: they are the perpetual motive
ng to action.

hing, as we have seen, is even more directly
y to life than food; but to this we are differently
hed. An appetite implies intervals of satiety
fference. The uninterrupted action of breathing
t be supported by a perpetual desire: we cannot
such a uniformity of sensation. The action of
g has been made instinctive, while pain and the
death are brought as the only adequate agents
ol the irregularities of a function so necessary to
ain does here what desire and the solicitation of
could *not accomplish.*

XIV.

THE STOMACH OF THE HORSE.

WHEN we think of the adaptations of animal structu
the different conditions of living creatures, the camel, t
ship of the desert, immediately occurs; and no do
it is highly interesting to observe how this anim
adapted to the sandy waste, in its eye, its nostril, i
foot, the cells of its stomach, and its capacity of en
ance. But it is, perhaps, more to our purpose to l
to our domestic animals, and the most of all deservi
attention is the horse.

Of all creatures, the horse has the smallest sto
relatively to its size. Had he the quadruple rumin
stomach of the ox, he would not have been at all ti
ready for exertion: the traveller could not have bai
his steed and resumed his journey. The stomach of t
horse is not so capacious, even when distended, as to im
pede his wind and speed; and the food is passing con
with a greater degree of regularity than in any oth
animal. A proof of this is, that the horse has no g
bladder. Most people understand that bile is neces
to digestion; and the gall-bladder is a receptacle for th
bile. Where the digestive process is performed in
large stomach, and the food descends in larger quantiti
and at long intervals, the gall-bladder is necessary;
there is that sympathy between the stomach and gal
bladder, that they are filled and emptied at the sa
ie. The absence of the gall-bladder in the hors
efore, implies the almost continual process of dige
which again results from the smallness of th
ch.

othe larity in the horse is the supply of sal ı the camel drinks, the water is deposited in cells cted with the stomach; but if a horse drinks a pail ter, in eight minutes none of that water is in the ch; it is rapidly passed off into the large intestine ıe cæcum. We cannot resist the conviction that ariation in the condition of the digestive organs of ɔrse, is in correspondence with his whole form and rties, which are for sudden and powerful, as well g-continued exertion.

XV.

OF THE GIZZARD.

THE gizzard is a favourite illustration with our autho he takes it up in Chaps. x. xii. xv. xvi., as the examp of compensation, relation, &c.

The bill of a bird has extensive relations both ext nally and internally. When we see a bird trimming l feathers with his bill, and combing out each feather fr the root to the point, we cannot but observe, that adm ably as feathers are formed for flight and for protecti against cold and wet, they would be inconsistent with t tongue and teeth of the quadruped. The rough tong would not penetrate to their interstices; nor would ruder operation of the dog's teeth suit the delicate tex of the quills. The bill, therefore, implies the absen teeth and of salivary glands. Lips and muscular ch are necessary for mastication; and however familia operation may be, a chapter might be well occupi show how cheeks and lips, salivary glands and teeth co-operate before a morsel can be swallowed,* an the derangement of one filament of the nerves sup these parts disorders the whole train of actions. W to show, then, how this function, deficient in the compensated by internal structure.

The gizzard is a fleshy stomach, the exact s for the muscles of the jaws, and teeth. Its s consists of a strong muscle; the dark part of th being the muscle, and the shining part of it the which the muscular fibres are attached. The ct, two muscles with a central tendon; it is what ana- mists call a digastric or double-bellied muscle. The vity within this muscle is lined with a dense, rough, sensible coat, and there are always to be found contained it small stones, generally of quartz, if it be within the ach of the creature's instinct to obtain them. The ains are mixed with these portions of stone; and if we it our ear close to a bird, we shall hear the grinding otions going on as distinctly as the noise of the horse's ws in the manger. In fact, this digastric muscle or zzard is equivalent to the muscles of the jaws, and the bbles are a fair equivalent to the teeth, with this advan- ge, that when they are ground down, the instinct of the rd supplies it with more. It picks up some small por- ns of gravel with as much alaarity as it will the grain elf. Some have supposed that this was sheer stu- dity in the fowl; but here surely instinct is better than ason.

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* See a paper on this subject, in treating of th *mastication*, in 'Phil. Trans.' for 1829.

When we recollect the provisions against attrition neces- ry to make the teeth last for the full period of the life a graminivorous quadruped, we are prepared to under- and the advantage of this beautiful and simple substi- ite, which, to so small a creature as the pigeon, gives an qual power over the material of its food, as the horse has ith its powerful jaws, and strong grinding teeth.

However, we are but describing a new instrument for rinding, or comminuting the food: yet this alone is not fficient to supply what was wanting in the mouth; and passing, we may observe that the gizzard does not ex- usively belong to birds. The gillaroo trout and the ullet have gizzards. The toothless ant-eater has a izzard: it lives on scaly and hard insects, such as beetles; id to assist in bruising them in its muscular stomach, it icks up pebbles like the domestic fowl.

Before the grain descends into this grinding apparatus f the bird, it is deposited in the crop; from the crop it escends, by little and little, into the cardiac cavity, as e first part of the stomach is called. In this latter ca- ity there are glands which secrete the gastric juice, and hich fluid is necessary to digestion. We should here also note a particular provision in the upper orifice of the gizzard, namely, the overlapping of a part of the muscle, which produces an obliquity in the passage, and holds the contents of the stomach confined during the strong action of grinding. It was indeed at one time supposed that such a mechanical operation of the stomach as we have described in the gizzard, fitted the food to supply the nourishment of the body; but, we repeat, that it has no further operation than that of comminuting the hard food, and preparing it for the action of this animal fluid, the gastric juice, which digests; and digestion is the first process of assimilation.

It may be interesting to the reader to know that the lower orifice of the gizzard, where it opens into the first intestine (*duodenum*), is differently guarded in different families of birds. In birds which have abundance of food, the gizzard has no valve to retard its escape; so that a greater part of the grains or seeds on which they feed passes off undigested; a fact which we touched upon elsewhere. Were birds of prey furnished with the same grinding apparatus which is suited for birds that feed upon grain, our argument would be overturned. But in them the gizzard is very weak; the cuticular lining of the stomach very thin; and the gastric glands, which pour out the digesting fluid, very large. In the hawk and kite we find no such macerating crop as in the domestic fowl.

Our author states that one class of birds cannot digest grains: the other cannot digest flesh. This, however, taken literally, does not accord with the experiments of Mr. Hunter, since he brought the carnivorous birds to live on grains, and the granivorous fowls to live on meat. But the necessity of accomplishing this change by very slow degrees leaves the substance of our author's argument sustained.

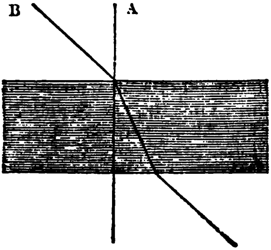
It is presumable that animal and vegetable matter are, in their ultimate elements, nearly the same; and, therefore, the last action of assimilation of the food is probably similar in all creatures. The variety of *organization* or *structure* in the stomach will be found to depend on the proportion of nutritious matter in the mass that is swallowed. A vegetable feeder requires, from the poverty of its food, to be continually digesting; and happily its food is in abundance around it. The carnivorous animal gorges its food, after long and irregular intervals; its prey is precarious; but then that food is richer in nutritious matter, and requiring to undergo only the last process of assimilation. The variety and complication in the structure of the digestive organs depending on the nature of the food, is not only exhibited in quadrupeds and birds, but in fishes and in insects. Insects that suck blood have a simple canal: the grasshopper and white ant, vegetable feeders, have a complicated canal. Just for the same reason the intestines of the lion are short and wide, and those of the goat long and complicated.

XVI.

ON THE RAYS OF LIGHT, THEIR REFRACTION AND REFLECTION.

THE nature of light has ever been a subject of controversy. It was Newton's explanation that luminous objects give out particles of inconceivable minuteness, and moving with extreme velocity. "What mere assertion," says Sir John Herschel, "will make any man believe that, in one second of time, in one beat of the pendulum of the clock, a ray of light travels over 192,000 miles; and would therefore perform the tour of the world in less time than a swift runner would make one stride?" In short, there is nothing like it but the influence of attraction; which is so instantaneous as to admit of no calculation of time at all.

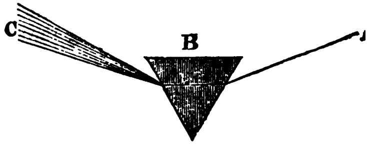
A different theory from that of Newton was suggested by Huyghens, who supposed a highly-elastic fluid to fill all space, and which, when moved, produced the effects ascribed to light. Instead of minute particles diverging from the luminous body, he substituted waves or vibrations, propagated through this elastic ether. The late Dr. Young, and some continental philosophers more recently, took up this hypothesis and supported it by ingenious experiments. But notwithstanding that it is the favourite theory of the day, difficulties appear still to encumber it. The theory of undulations implies the advance and recoil of the elastic medium, and that gives the idea of retardation. The supposition of light being the effect of the motion of an ether, does not fall in with our conceptions of the manner in which it enters into the composition of bodies, or influences chemical combinations, or affects the living powers of animals and ıbles. The merits of the two theories, however, ıot be discussed here. It will be sufficient for our ɜe to represent a beam of light by a line drawn he pen, and to enter on the explanation of a few laws which influence it in passing through trans- media.



en the ray of light, as A, passes perpendicularly ı rarer into a denser medium, as from air into it suffers no change in its direction; but when it obliquely, as B, it takes a new direction towards ːrpendicular, making a sudden angle, as if broken, this is refraction. Two circumstances, therefore, ıce the ray of light;—the angle at which it falls, e density of the body into which it passes. When y B passes from the denser medium into the rarer, gain refracted, but away from the perpendicular, ıkes its original course, provided the surface at it goes out is parallel to the surface at which it d.

ɩen a ray strikes upon a body that is not trans-, or only imperfectly so, it is in part reflected, that ıck off again, bent back, or reflected, and enters e, conveying to us the impression of the form and of that object.

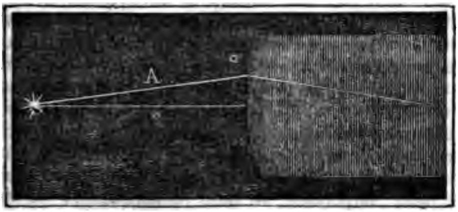
the expression which we have used requires explanation; for how is it that the reflected ra convey the idea of colour?



The prism is a piece of glass so formed tha must fall obliquely on one or both of the sur suffer refraction. Thus the ray A striking into B is refracted; but all its parts are not equally and as the light consists of parts differing in co which are differently refracted, it is divided or into several colours C, called the prismatic colo spectrum, as it is termed, thus formed, consist colours; that which is least refracted being in succession orange, yellow, green, blue, in violet. If these rays be re-compounded b through a convex lens, which, owing to the with which they fall, draws them to a point, of the light will be again colourless. Som philosophers have reduced these prismatic c Newton to three primary colours, red, yellow, contriving, by the super-position of these, to the seven tints; while others have, on cons not easy to be disproved, held that there is no finite number of colours, but a gradation of the extreme red to the extreme violet.

We may now understand the reason of the objects. When light strikes upon a body, e the most transparent, part penetrates, part is and some part is lost. A dye is a disposition the surface of cloth to repel some of the rays more than the others; and the colour will be to the ray, or the combination of rays, thus and sent into the eye.

And here it is natural to reflect on the va ıty everywhere bestowed through this property of beam of light. What a dulness would have per- ed the surface of the earth if there had been only a te light! The beauties of the garden and of the scape would have been lost to us. How is the ıty of the latter enhanced by the almost infinite ety of colour, yet still within that range which is eable and soothing to the eye, as well as consonant ur feelings! The human countenance, too, although ıble of exciting our warmest sympathies by form and ion alone, has that beauty perfected by colour, vary- under the influence of emotion.



t remains, in order that we may apply these facts to explanation of the structure of the eye, to show how rays proceeding from a body and falling upon a con- glass suffer refraction. The ray that strikes upon centre, being perpendicular to the glass, passes on eviatingly. But each ray as it strikes a point re- ed from the centre, must impinge with more obli- y, in consequence of the curved surface; and as the action of all the rays will be in proportion to the quity of their incidence, they will converge towards central direct ray. Thus A, as it passes through glass, suffers refraction towards the perpendicular , in proportion as it deviated from it, on passing out the air into the glass. These few simple statements suffice for understanding the comparison which we now to make between the eye and optical instru- nts.

XVII.

THE EYE COMPARED WITH OPTICAL INSTRUM

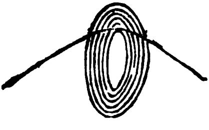
We have elsewhere expressed our surprise
structure of an animal body should so seldom
as a model. In the history of inventions, it
quite extraordinary that the telescope and the mi
should be modern, when, as it should seem,
transparent convexity of the eye might have give
imitation, as soon as man learned to give shape t
or artificial glass. It reminds us of the obser
Locke, in speaking of a discovery, that it pr
world to be of no great antiquity. Yet we must
the invention of the telescope and microscope a
the most important in their consequences o
ancient or modern discoveries. The first opens
unlimited expanse, not only of new worlds, but
of worlds, and new laws evinced in the force
propel and attract these; since in the heavenl
we find no material contact, nor pressure, nor i
nor transfer of power—nor effect of heat, nor ex
of gases—nothing, in short, which can be illustr
mechanism. By the microscope, we contempl
minute structure of animals and things but for
invisible: the balance of the cohesive and re
forces as they order the changes in the material
world, and in that of our own frames. Yet th
struments are not in contrast with the eye: but
the comparison of them we discover the wonderfu
ations of that organ; of which it has long a
said, that it can at one time extend our conten
to the heavenly bodies and their revolutions, an
other limit its exercise to things at hand, to

ies and affections of our nature visible in the coun-
nce.

we put aside the consideration of the living pro-
ies of the organ, as the extraordinary variety and
ees of sensibility in the nerve of vision, and confine
elves to points easily comprehended, as, for example,
mechanism of the eye, and the laws of optics as ap-
ible to the humours, we shall find enough to admire.
hen we look upon the optician's lens, however per-
its polish may be, we can see its convex surface:
is to say, the rays of light which strike upon that
ce do not all penetrate it, but are in part reflected to
eye, which is the occasion of our seeing it. We do
see the surface of the cornea of the human eye.
e, then, is an obvious superiority, since it implies that
he rays of light which strike the cornea enter it and
efracted, and none are returned to our eye. If we
the optician's lens between our fingers and hold it
r water, we can no longer see it, however transpa-
the water. The reason of this is, that the rays of
are reflected when entering from a rare medium into
ser, more abundantly in proportion to the difference
density. When the ray of light has penetrated
ter, it also penetrates the glass, because there is not
ifference of density between the water and the glass
there is between the atmosphere and the glass.
his we may estimate the importance of the surface
ornea being moistened by the tears; for however
he water may be spread over the surface of the
s sufficient to make those rays that would other-
reflected penetrate the cornea.

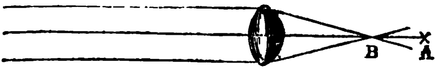
hole humours of the eye are constituted with a
this law. There is nowhere an abrupt transi-
a rare to a dense humour. The ray is trans-
m the cornea into the aqueous humour, and
at humour into the lens or crystalline humour.
latter humour uniform and of the density of its
t throughout, the ray would be in part reflected
its surface. But it is not uniform, like a mass
consists of concentric layers increasing in

density from the surface to the centre. If we first look at the entire lens, and then take off its concentric layers, we shall see the surface of the internal nucleus more distinctly than the exterior and natural surface. The reason is obvious: the nucleus is so much more dense than the atmosphere, that the reflection of the rays from it is more abundant. We now comprehend how finely it is provided that the crystalline lens should be surrounded with the *liquor Morgagni*, a fluid which is but in a slight degree more dense than the aqueous humour. The exterior surface of the lens itself is only a little more dense than the surrounding fluid, and each successive layer, from the surface to the centre, is of gradually increasing density: so that if we were to describe the course of the ray, it would not, as we see in the ordinary diagrams, pass like a straight line of the pen, but in a curved line,



showing the gradual manner in which the ray is refracted through successive transparent layers. As it enters in the anterior half of its passage, it encounters media of increasing density: but as it passes out behind, it is transmitted through media diminishing in density. The ray is nowhere opposed by that sudden increase of density which gives a disposition to reflection; and it passes through the vitreous humour still refracted, the density of that humour having a just correspondence with the posterior surface of the lens. In the atmosphere there is a similar arrangement for receiving the light proceeding from the sun or stars: for as the density of the air diminishes as the height above the earth increases, the surface of our atmosphere, from its rarity, must almost resemble free space; consequently the light falling into it will penetrate more abundantly than if the air were compressed as it is near the earth, and were of uniform density. We us see the obvious superiority in the structure of the eye any thing that can be composed of glass, which is of iform density throughout, and must therefore present a ccession of surfaces where rare and dense media are ruptly opposed to the rays transmitted.

We may observe another happy result from the pecur structure of the lens. A magnifying glass is never ue; an aberration of the rays takes place in the pencil light, as the rays are drawn to a focus. The rays hich penetrate near the centre are projected so as to drawn to their focus beyond those rays which pierce rough nearer the edge. The rays penetrating the ntre of this double convex glass will project the image A, whilst those penetrating nearer the circumference, d consequently falling more obliquely, will form a cus nearer the lens at B. But in the crystalline mour of the eye, which corresponds with the optian's lens, the exterior layer having less density, and erefore a diminished property of refracting the ray, the age is carried farther off to A; and by this means it is dered that, wherever the ray penetrates, it shall be awn to an accurate focus.



Some modern philosophers have asserted that the eye not perfectly achromatic in every adjustment. The rm implies the property of the instrument to represent image divested of the prismatic colours; those false lours which attend the refraction of the rays of light. the statement be correct, it is nothing against our gument; nor have those inquirers advanced it with any ch view.* We know that in all the ordinary exercises the eye the image is perfect, having neither penumbra r prismatic colours. This property of the eye results

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[*] Professor Blair (*Edinburgh Transactions*, iii.) expressly rives an argument in favour of design from this statement his opinion, and his objection to Boscovich.

from the different media through which the rays are transmitted, and the gradual transmission which we have just mentioned. Dollond's achromatic glasses, a great improvement upon the telescope, were made on this principle. He composed the object-glass of the telescope of crown-glass and flint-glass; so that while, by the combined effect of their convexities, they drew the rays to a focus, the dispersive power of the one was counteracted by that of the other.

Let us endeavour to explain this. A, a beam of light, being composed of the different coloured rays, passes through the prism B. (See Fig. p. 92.) Instead of passing onward in a straight line, it is refracted to C in distinct and, consequently, coloured rays. Whilst the whole of them are bent or refracted at an angle from the dotted line, they are also diverging from one another. Their deviation from the straight line is their *refraction*; their diverging from each other is their *dispersion*. These properties being distinct, it is conceivable that glass of a different chemical composition may affect the one to a greater degree than the other, and, therefore, that a lens may be composed of different kinds of glass (crown-glass and flint-glass, for example), so that the convergence of the rays into a focus may be obtained without the dispersion of the rays, and the consequent production of false colours round the image. This is what Dollond nearly accomplished, and upon these principles. That the effect of this very artificial arrangement is attained in the eye is a remarkable proof of the perfection of its adaptation to the properties of light.

The last circumstance which we may mention in continuing the comparison, is the drawing out of the tube in the telescope to accommodate the foci of the glasses to the distance of the object. It is sufficient to say that the eye possesses this property of accommodation. That we do not understand how the operation is performed, only strengthens the argument in favour of the perfection of the eye; since the power exists, and is exercised with an ease which hardly permits us to be sensible of it.

XVIII.

HE MEANS BY WHICH THE EYE IS PROTECTED.

an astronomer, in the darkness of night, and
from the light of his chamber, moves his telescope
ar to star, his eye is accommodated to faint im-
is; that is, the sensibility of the retina is then
ated, so that when he directs his instrument to
;hter objects his sensation is painful. And if, at
time, he should be observing the sun, without
guarded the eye by smoking the glasses, or by
ther means diminishing their transparency, the
ipon the retina will not only be painful, but may
estructive to its fine texture, and occasion a defect
n which will continue through life. If the appa-
i the tympanum of the ear be destroyed, and the
supplied by an ear-trumpet, the person will be
by those who speak into this trumpet; for if
: not in the habit of pitching their voices dis-
and softly, the sound will jar painfully upon his
'y these considerations we are prepared to con-
e that beautiful provision by which the natural
protected against the sudden intrusion of light, or
intense illumination of the object upon which it
:ed.

iris is a curtain, or septum, which stretches across
ieous humour, and is anterior to the crystalline
; is perforated in the centre, and that perforation
upil—the black central spot which we see when
c into the eye—black, for the reason which we
signed, that the rays piercing there are not re-
and the absence of rays is blackness. But the
ike the anterior part of the iris itself round the

perforation, and they are partially at least reflected, giving the colour to the eye—grey, or blue, or hazel.

Perhaps the diagram (vol. ii., p. 22) will explain the structure of the iris and pupil, and show the mode in which the pencil of rays is enlarged or diminished, and the intensity of the image in the eye thus made greater or less in proportion to the illumination.

The iris, then, we understand to be a muscular septum or partition, with two sets of fibres; a straight set converging to that margin of the iris which forms the pupil, and a circular set running round the exterior margin of the iris. At page 189 of vol. ii. we have given a representation of the iris of the lion. The pupil or open space is oval in this animal; B B are the straight fibres converging to the exterior margin of the iris; and C C are the circular fibres of the margin. These two sets of fibres act against each other, and in a moderate light the pupil is moderately expanded; but when the light is obscure, the circular fibres relax, and the straight fibres act; the iris is then diminished in diameter, and the pupil enlarged. The contrary takes place when too intense a light strikes into the eye.

This guardian action of the iris is more rapid than words, and as quick as thought; and it is to be remarked that this apparatus is animated by nerves which go back to the sensorium; so that the impression must be received in the sensorium before the iris can be directed in its motions.

Such, then, is the apparatus by which the nerve of vision is guarded; and as marking its necessity, let us remember that the retina is susceptible, in an extraordinary degree, of various impressions of light, that it will be sensible to an object illuminated as one, and as thirty thousand. It is obvious that either we must have groped in the dark during the evening or moonlight, or have been quite dazzled and overpowered by the brightness of the sun, had not this fine mechanical apparatus of the iris been adapted and assigned for the protection of the nerve.

But the nerve is protected in another way, or rather,

d say, the force of the impression is regulated.
: seen that the colours of objects are owing to
of light being reflected from them; that on a
erfectly black the rays sink in and are lost, and
gnise the object only by its outline being con-
vith surrounding coloured bodies, not by the
ected from itself. When the eye of an animal
ed for the bright light of day, a black pigment
d the nerve, and the nerve itself being trans-
the ray is transmitted and lost. But if it be
that the eye shall be suited to the habits of an
at prowls by night, then there is combined with
eye and the very dilatable pupil, calculated to
great pencil of rays, a property of reflection in
um or carpet; that is, the surface at the bottom
e on which the nerve is expanded. Instead of
k and absorbing pigment, there is a secretion
d by that surface, which, like a dye, throws off
ts the light, or reflects it back like the silver on
of a mirror. This gives a second impulse to
e, and has the effect of doubling the force of the
on.

s now see how an organ of the extreme trans-
and delicacy of the eye is guarded from injuries
er kind.

first, we may observe the combination of the
operties with the motion and mechanism of the
; how the extreme delicacy of the surfaces of
has adapted to it the fine sensibility seated in the
and roots of the eye-lashes. The pain excited
smallest particle that floats in the atmosphere
e the source of constant suffering, were there not
d with and animated by the same sensibility an
s, mechanical and hydraulic, for the obvious
of ridding the delicate surface of the eye of all
natter.

here be anything more interesting than to find
le of this apparatus under the guidance of a pro-
fferent from that of consciousness and volition?
e seen many instances of persons deprived of the

sensibility of the surfaces of the eye from the a
of one nerve alone, without the loss of vision, or
motions of the eye-lids, or of the flow of tears; bu
been impossible in such persons to preserve the
by assuring them of the necessity of these n
either through the direct action of the eye-lids, or
aid of their fingers. The eye's surfaces, being d
of sensation, are no longer regularly moistened; s
dust rest upon them; and, although they are ins
they inflame; the transparent cornea becomes
and the eye is lost. This is the consequence ne
the want of sensibility in the retina, nor of the c
of motion in the eye-ball and eye-lids being lost
failure of the spring of water that runs continual
the eye: it results simply from a loss of that rel
the sensibilities suited to the materials and in
around us, and the protecting motions which they
It at once answers the querist who asks, why w
pain? We reply to him by another question. H
we to hear or see, or how enjoy the sense from
sions so delicate as those of sound and light; or e
these, by instruments so exquisitely framed, how a
instruments to be protected from the ruder sh
which they must be exposed? These consid
lead to the conclusion that if he object to one par
system, he objects to the whole of that by which
our present existence.

The motions of the eye and eye-lids, which are
by this sensibility, must be performed with extr
pidity. To rinse anything in water, or to rid it
by shaking it in the wind, the action must be quic
such a motion is possessed by the eye of the fish, a
the eye-lids and lachrymal apparatus are in them
cessary.

If we are giving proofs of design, we can hav
more obvious than that suggested in the Prelimina
course, in the eye of the mud crab, an animal whi
the eel, seeks its food in mud and turbid water.
ing from such a bed, its eye is covered with sli
would be useless: but to provide against this inc

re is a little brush near the eye, to which the
nt horny eye can be raised, and against which it
, with an action as intelligible as that of a man
iis spectacles. The cray-fish, too, which burrows
inks of rivers, has the same provision, although
ture is less perfect.

assumed that the action of the eye of fishes is
I must confess that I have not seen this, but we
led to conclude that they possess the motion, as
ve other muscles besides those necessary to direct
muscles which, by the oblique direction of their
re calculated to give extraordinary rapidity of
nd resemble that apparatus which gives the rapid
e motions to our own eye.

rst time that we observe any remarkable pheno-
ey excite more emotion, and we describe them
e interest. I shall therefore extract here a por-
paper given to the Royal Society on the nerves
e, which it was necessary to preface by observa-
the actions of the muscles, a subject which I con-
ad not been fully understood.

XIX.

MOTIONS OF THE EYE-BALL AND EYE-LIDS.

WE shall consider the muscles of the eye, first, as n
sary to its preservation; secondly, as necessary to
the organ of sense. We do not reflect on those a
of our frame which are most admirable in thems
which minister continually to our necessities, and p
the exercise of our organs, until we are deprived of t
like unnatural children, unconscious or unmindful
dulgence, we feel only the loss of benefits. "With
compassion," says the religious philosopher, "as w
astonishment at the goodness of our loving Creator,
I considered the sad state of a certain gentleman w
to the rest, was in pretty good health, but only w
the use of those two little muscles that serve to lift
eye-lids, and so had almost lost the use of his sight,
forced, as long as this defect lasted, to shove up hi
lids with his own hands." I have often thought o
saying when I have seen a patient in all respects in h
but without the power of raising the eye-lids.

There is a motion of the eye-ball, which, from i
pidity, has escaped observation. In the instant th
eye-lids are closed, the eye-ball makes a movement
raises the cornea under the upper eye-lid.

If we fix one eye upon an object, and close the
eye with the finger, so as to feel the convexity
cornea through the eye-lid, we shall perceive wh
the eye that is open, that the cornea of the oth
antly elevated; and that it thus rises and fa
thy with the eye that is closed and op
han [illegible] ition of the eye-ball takes
t [illegible] winking motions of the ey

When a dog was deprived of the power of closing the eye-lids of one eye by cutting across the nerve of the eye-lids, the eye did not cease to turn up when he was threatened, and when he winked with the eye-lids of the other side.

Nearly the same thing I observed in a girl whose eye-lids were attached to the surrounding skin, owing to a burn; for the fore part of the eye-ball being completely uncovered, when she would have winked, instead of the eye-lids descending, the eye-balls were turned up, and the cornea was moistened by coming in contact with the mouths of the lachrymal ducts.

The purpose of this rapid insensible motion of the eye-ball will be understood by observing the form of the eye-lids and the place of the lachrymal gland. The margins of the eye-lids are flat, and when they meet, they touch only at their outer edges, so that when closed there is a gutter left between them and the cornea. If the eye-ball were to remain without motion, the margins of the eye-lids would meet in such a manner on the surface of the cornea, that a certain portion would be left untouched, and the eye would have no power of clearing off what obscured the vision, at that principal part of the lucid cornea which is in the very axis of the eye; and if the tears flowed they would be left accumulated on the centre of the cornea, and winking, instead of clearing the eye, would suffuse it. To avoid these effects, and to sweep and clear the surface of the cornea, at the same time that the eye-lids are closed, the eye-ball revolves, and the cornea is rapidly elevated under the eye-lid.

Another effect of this motion of the eye-ball is to procure the discharge from the lachrymal ducts; for by the simultaneous ascent of the cornea, and descent of the upper eye-lid, the membrane on which the ducts open is stretched, and then the tears flow unimpeded.

By this simultaneous motion, also, the descent of the eye-lid and the ascent of the cornea, the rapidity with which the eye escapes from injury, is increase
creatures which have imperfect eye-lids, as fis

sessing this rapid revolving motion of the eye, avoid i jury and clear off impurities.

I may observe, in passing, that there is a provision f the protection of the eye, in the manner in which t eye-lids close, which has not been noticed. While t upper eye-lid falls, the lower eye-lid is moved towa the nose. This is a part of that curious provision for c lecting offensive particles towards the inner corner of t eye. If the edges of the eye-lids be marked with bl spots, it will be seen that when the eye-lids are ope and closed, the spot on the upper eye-lid descends a rises perpendicularly, while the spot on the lower eye- will play horizontally like a shuttle.

To comprehend these actions of the muscles of the e we must remember that the caruncle and membr called *semilunaris*, seated in the inner corner of the e are for ridding the eye of extraneous matter, and are, fact, for the same purpose as that apparatus which is m perfect in beasts and birds. The tears are imbibed the *puncta* or orifices, which may be seen in the in corner of the eye; and a tube, formed on the princi of a siphon, carries them into the nose: whilst the d washed to this corner, is thrown out by the appara which we have described.

The course of our inquiry makes some notice of th parts necessary.

In quadrupeds there is a gland for secreting a glutin and adhesive fluid, seated on the side of the orbit next nose: it is quite distinct from the lachrymal gland; i squeezed by an apparatus of muscles, and the fluid exu upon the surface of the third eye-lid. This third eye- is a very peculiar part of the apparatus of protection. is a thin cartilage, the posterior part of which is attac to an elastic body. This body is lodged in a division depression of the orbit on the side towards the no When the eye is excited, the eye-ball is made to press the elastic body against the side of the orbit and force out of its recess or socket; the consequence of which the protrusion of the cartilaginous third eye-lid, or *ha* as it is termed in the horse. By this mechanism the third eye-lid is made to sweep rapidly over the surface of the cornea, and, by means of the glutinous fluid with which its surface is bedewed, it attaches to itself and clears away offensive particles.

In birds, the eye is an exquisitely fine organ, and still more curiously, we might be tempted to say artificially, protected. The third eye-lid is more perfect than that of quadrupeds: it is membranous and broad, and is drawn over the surface of the eye by means of two muscles attached to the back part of the eye-ball, one of which acts by a long round tendon, that makes a course of nearly three parts of the circumference of the ball.* The lachrymal gland is small, and seated low, but the mucous gland is of great size, and placed in a cavity deep and large, and on the inside of the orbit. As the third eye-lid is moved by an apparatus which cannot squeeze the mucous gland at the same time that the eye-lid is moved, as in quadrupeds, the oblique muscles are particularly provided to draw the eye-ball against the gland, and to force out the mucus on the surface of the third eye-lid. It flows very copiously; and this is probably the reason of the smallness of the proper lachrymal gland which lies on the opposite side of the orbit.

We already see two objects attained through the motion of these parts: the moistening of the eye with the clear fluid of the lachrymal gland, and the extraction or protrusion of offensive particles.

There is another part of this subject no less curious: the different conditions of the eye during the waking and sleeping state. If we approach a person in disturbed sleep when the eye-lids are a little apart, we shall not see the pupil or the dark part of the eye, as we should were he awake, for the cornea is turned upwards under the upper eye-lid. If a person be fainting, as insensibility comes over him the eyes cease to have speculation; they want direction, and are vacant, and presently the white part of *the eye is disclosed* by the revolving of the eye-ball u

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* See p. 33, vol. ii.

wards. Look to a blind beggar; those whit
not turned up in the fervour of entreaty; it is
state of the eye-balls, which are totally blind,
the exercise of which the individual has with
attention. So it is on the approach of death; fo
the eye-lids be open, the pupils are in part
turned up with a seeming agony, which howe
mark of increasing insensibility. These motion
for the protection of the organ do not inte
vision; they are performed unconsciously, and
that the impression of the object on the retin
time to vanish in the interval. The motions o
ball for directing the eye to objects are strictly
and are always connected with the exercise of
of vision.

It will now be admitted that the variety of t
of the eye requires the complication of muscles
find in the orbit, and unless the various offices
ent conditions of the eye be considered, it will
to attempt an accurate classification of the
nerves of the orbit.

XX.

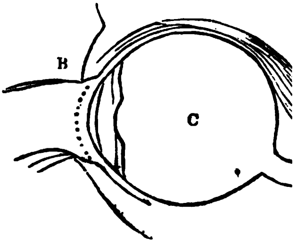
MUSCLES OF THE EYE-LIDS.

VEN in the action of the muscles of the eye-lids, although
e most exposed and familiar parts of any, there is some-
ing new still to be observed. The eye-ball is held
twixt the *levator palpebræ*, the muscle which raises the
e-lid, and the *orbicularis*, that which depresses it; the
e as it elevates the eye-lid tending to protrude the eye-
ll, the other to compress and restrain it.

In paralysis of the *orbicularis*, the muscle which closes
e eye, the eye-ball is protruded; it starts more forward
an is natural; the eye-lid is loose and flabby, and can
lifted like a bit of common skin.

It is from this protrusion of the eye-ball that the upper
e-lid is raised, and the lower eye-lid depressed, by one
uscle. Anatomists have sought for a depressor of the
ferior eye-lid, seeing that it is depressed; but such a
uscle has no existence, and is quite unnecessary. The
vator palpebræ superioris opens wide the eye-lids, de-
essing the lower eye-lid at the same time that it elevates
e upper one. If we put the finger upon the lower eye-
d so as to feel the eye-ball when the eye is shut, and
en open the eye, we shall perceive that, during this
tion, the eye-ball is pushed forwards. Now the lower
ye-lid is so adapted as to slip off the convex surface of
e ball in this action, and thus to be depressed, while
e upper eye-lid is elevated.

The origin of the levator being at A, and the insertion
to the cartilage of the upper eye-lid at B, the effect of
e action of the muscle must be the protrusion of the eye-
all C to the dotted line. By the elevation of the upper
ye-lid, the eye starts forward a little, and the lower



eye-lid therefore slips off the lower se
ball.

It is curious to observe how the eye
condition of repose, and is protruded
exercised in vision. High excitement,
the eye-balls are largely unclosed, is
increase of the sphere of vision produ
sion of the eye-balls; a change remar
ferocious and timid animals, especially

Such were the views of the motions
eye-lids, introductory to a paper on t
eye – itself introductory to observation
the orbit. The discussion relating to
and minutely anatomical for our presen
be sufficient if I state the deduction,—
muscles around the eye, and the six ne
mities reach them, two sets of motions
first for the voluntary direction of th
sympathy with vision; the other in c
mechanical and hydraulic apparatus fo
the organ. When we enjoy the sens
luntary muscles are excited; but, in s
preponderates, over which we have n
and this is the condition of rest as wel
organ.

XXI.

VIEW OF THE USES OF THE PARTS IN THE EAR.

find late physiological writers acknowledging their rance of the functions of the particular structures in organ; and we cannot therefore conceal that there is fficulty in assigning the uses of the parts. Never- ss, we shall now endeavour to explain our concep- of this matter; and, at all events, there is enough rove the main argument of design and of the fine tation of this organ to the laws by which sound is pro- ted.

he outward ear of man and animals is so obviously ided for collecting sound that there can be no cavil . It is extended and moveable in those animals h hear acutely, and in some, as the bat, it is double, isting of one expanded membrane within the other. this brings to mind an assertion, that the membrane e tympanum is affected by the vibrations of the side e auditory tube more than by the direct impulse of tmosphere against it; for if there be one conical ex- ed external ear within another, it is obvious that there be a larger surface to receive vibrations and commu- e them to the tube and membrane of the tympanum. suffices with some to say that the undulation of sound ceived upon the membrane of the tympanum, and by communicated to the atmosphere within. But how e infinite variety of sounds, all, in fact, that we hear, municated simultaneously through the same mem- e? In the first place, the membrane is not simple, is it muscular, but contains within it cords or fibres h run from its outer margin, converging towards the eus. It is now that we look with great interest upon

the experiments of Chladni and others on n
He strews dust upon one of these plates, ar
out a note by drawing the bow of the vi
edge; when the sand, or powder, or dust
itself in regular figures. These figures a
for their symmetry, dividing the circumf
plate into equal parts, from six to forty; o
vides itself into circles having the same ce
plate, and the diametrical and circular line
produce an astonishing variety in the config
particles. Here, then, we have a proof tl
there being a general undulation or vibratio
membrane of the tympanum, it may be
motion taking place in its minute parts, and
many nodes or centres which remain m
short, we perceive a capability of motion in
corresponding with the variety of sounds wl
to be propagated through it. And if we sl
that the general surface of the membrane v
for so great a variety of compound motion
visible upon its interior surface may be cor
cient to allow it to correspond with every p
of note. (See fig., vol. ii., p. 41.)

How satisfactory soever the ingenious e
acoustics and with musical instruments may
difficulty which has not been met in assigni
to some of the parts in the ear. The c
in the tympanum undoubtedly communica
from the membrane of the tympanum to th
of the sense, the labyrinth; and nothing is n
to conceive that the membrane of the tymp
ing an impulse, like a sail flapping by the
communicate the same to the malleus and in
the other bones. But the difficulty arises f
ing that it is not a mechanical impulse whi
nicated, but a motion of sound. When philo
us the nature of sound by throwing a pebb
pond of water and making us observe the c
dulations: or by striking a cord and observi
which accompany the sound, and showing

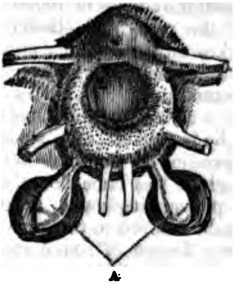
subdivisions, we seem to have overcome all the difficulties of the science. But we encounter new difficulties when we are forced to conclude that all the combinations of sound in an orchestra, for example, are transmitted through a chain of bones, some of which are not greater in diameter than a horse-hair. We are reminded that the undulations visible to the eye or felt by the finger are not the motions of sound, although they accompany them, and that they must be of a nature much more minute and delicate. There is no instance of one organ of sense conveying the knowledge of a quality of matter for the perception of which another organ is provided. Still, perhaps, these microscopic observations may assist our invention. When a powerful lens is applied to a metallic cord sounding, and we distinguish the brilliant particles on its surface, those particles have not the motions merely to and fro which are caused by the division and subdivision of the elastic cord: those brilliant particles dance in figures infinitely varied, combined of circles and angles which it is perhaps impossible to describe and reduce to any system. Such facts aid us in comprehending how different motions of sound may be communicated at the same moment.

It is ascertained that if a metallic rod be placed in contact with a sounding-board to which the sounds of many instruments playing in concert are communicated, and if that rod be extended to a great length, or if it be carried through a partition, so that we are out of ear-shot of the instruments, and if the rod communicate at its further end with another sounding-board, the motions of that board will be given out to the atmosphere, and we shall hear the concert, that is, the combined sounds of the instruments, although necessarily faint. Here, then, the music must have been conveyed along the rod; and we have another proof that sound cannot consist of those coarser movements ascertained by the other senses, but of something so infinitely more minute that the particles in the rod may convey distinct vibrations simultaneously. These considerations certainly countenance our belief, that however fine the chain of bones may be which, passing through the tympanum, communicates between the externa internal ear, it is yet capable of a variety of motion responding with the sounds, of which the ear i ceptible.

What, then, is the meaning of this very o mechanical structure in the chain of bones in th levers and their attached muscles? (See fig. p. 3 ii.) Are not the three muscles attached to the bo is fixed to the membrane calculated to affect the t of the membrane? If we take the illustration in th we must remember that the military drum is not so as it has been represented. The chords or braces pass outside the drum obliquely, are tightened by down the knots of buff leather, and this not only st the parchment head of the drum, but tightens th or cords which run over the parchment of the re e the drum. In the military drum, it is the blow on parchment that gives the loud and sudden sound ; wh the chords alter and prolong the sound. The th muscles which are attached to the malleus and through i to the membrane of the tympanum we must suppose may either brace or throw loose the membrane and its cords; as the drum is braced or muffled: and in this way the small muscles of the tympanum may have a resemblance in function to the fibres of the iris; they may guard the nerve of hearing as the latter does the nerve of vision. We had occasion to observe, that when a person is deaf from the disorder of this apparatus, and when he substitutes the ear-trumpet, he may hear; for the ear-trumpet, by its expanded mouth, collects the undulations of sound and concentrates them; but there is this imperfection, that the ear wants its power of adjustment; and the person is accordingly often timid in the use of his instrument with those who are not accustomed to speak to him, the sound of some voices being painfully harsh. Further, we may not hear a sound when called upon to listen to it, and yet when the particular sound is described, we do hear it; now it remains to be determined whether this be a power of adjustment in the ear, or owing to the effect of association in the mind.

supposed by some that there are two tracts by und is communicated to the labyrinth; that it th through the chain of bones and through the e tympanum. With regard to the last mode, I ceive no cavity less suited to convey sounds. f having a definite form like the tube of the ear, the vibrations might be received and directed the tympanum opens into the cells of the tem- e, and presents the most irregular surface pos- such as would inevitably break and destroy any ound. The extension of cavity of the tympanum ted to increase the elasticity of the air in the m, but most certainly not to collect or to n the sound.

regard to the labyrinth, comparative anatomy onsiderable assistance. Were vibrations of sound mmunicated to the brain the cause of hearing, the lf would be the organ and no special nerve ne- The brain in some animals, being placed in a d surrounded with fluid, is subjected necessarily ion. But we perceive that in addition an appro- rve and distinct organ are bestowed. There is the cuttle-fish, very little apparatus in this organ,



ure represents the form of the brain in the cuttle-fish, as e of its very simple structure: A the simple auditory

it proves that the essential part of the ear is the nerve
eptible of sound, and not the exterior apparatus.
ne sixty years ago, learned men in Italy wished to as-
tain whether the lobster had the organ of hearing or
. The celebrated Professor Scarpa, then a young
n, undertook to decide that matter; not by looking for
exterior organ, but by examining the brain and the
ves which go out from it. Finding that there was a
ve which stood in the relation of an acoustic nerve, he
ed it onward, and found it terminating in a little sac
taining fluid, and open to the influence of the atmos-
ere by a small membrane which crossed the mouth of
This was the just and philosophical mode of pro-
ding. There being, in fact, nothing in the brain
lf, with respect to its exposure to tremours or motion,
erent from the auditory nerve, if that nerve had had
rely to convey a vibration to the brain, it would have
n superfluous, as the brain itself would have vibrated.
nce we perceive that an endowment of a nerve which
ll be susceptible of the sense of sound is necessary,
consequently it is the primary and essential part of
organization. How the motions of sound shall reach
s another question.

Let us now carry along with us the fact that solids and
ds are much better vehicles of sound than the atmos-
re; that it is the rarity and elasticity of the atmos-
re which makes all that exterior apparatus which we
e been considering necessary. Accordingly, an exte-
r ear is not wanted in the fish. If a man dive under
ter and carry a stone in each hand and strike the
nes together, he is sensible of a stunning sound, and
eed of an impression on the whole surface of his body.
short, although it was once doubted whether water
re capable of propagating sound, a hundred instances
now be brought forward to prove that it can receive
propagate every degree of sound and tone. Again,
en we find that the solid parts of the head convey
nds, we perceive that in the fish there is no occasion
n for an external opening, far less an external ear.
apparatus of a totally different kind is bestowed.

a little sac of fluid a bone or concretion is sus-
which, being more solid than the surrounding
ceives the vibration, and moves, necessarily pro-
waves or motion in the surrounding fluid, and
ently an agitation of the extremities of the nerve
to the fluid. A very simple but curious experi-
' Professor Camper illustrates the effect of this
e: A bladder containing a marble and full of water
eld in the hand, the slightest motion of the hand
ended with a vibration communicated from the
the hand: the effect of the motion of the marble
e surrounding water.

respect to the semicircular canals above described,
; a loss to understand what is meant by some
saying that their use is not known. These canals
of an elastic membrane full of fluid, with a nerve
ed upon the septum of one extremity: are they
admirably suited to receive the impulses which
eyed through the bones of the head? That they
is clear from their being found in the heads of
here there is no access of vibration to the nerve
through the bone. But we are affected by the
en our head is on the pillow and we are awakened
le moving in the house: the alarm is through the
nes of the head. And when the Indian puts his
e ground to hear a distant tread, he is substitut-
communication through the solids and the bones
ead for the atmospheric impulses.

n, let us recur to the proposition that sound is
ted to the internal ear in two ways: through the
' bones and fenestra ovalis into the vestibule, and
ough the air of the tympanum, and by the fenestra
into the cochlea. There appear strong objec-
this doctrine. It declares the chain of bones and
pended muscles and beautiful articulations to be
er useless; for if the sound can be communicated
the air of the tympanum, what is the meaning of
plex apparatus? And if the bones of the ear
icate better, what is the use of the vibration
by any other course? Let us understand, then,

that the whole exterior apparatus—that is to say, the parts exterior to the labyrinth—are necessary only to perfect hearing, and that when they are all gone by disease, the essential parts of the organ which we see suffice in the lower animals, continue to receive sounds.

The apparatus of bones and muscles connected with he membrane of the tympanum (see vol. ii., p. 39) is of more consequence than physiologists allow. It is essential to perfect hearing, even when the sound is conveyed through the solid bones. If we hold a watch between the teeth, the sound is propagated through the solid parts; but let us compress and close the outer tube of one of the ears, and the sound will be increased on that side. If a person, being deaf in one ear, put his watch close to that ear, he will not hear the ticking; but, if at the same time he presses on the tube of the other ear and closes it, he will then hear the ticking on that side. It appears that in this experiment, the sound propagated through the bones is not given directly to the nerve, but to the membrane and bones of the tympanum, and through them back upon the nerve. The air in the outer tube of the ear, being pent up by the pressure of the fingers and compressed, receives the vibration, reverberates on the membrane of the tympanum, and puts the apparatus within the tympanum into play.

Drawing a fair inference from the demonstration, it would appear that the impulses upon the membrane of the tympanum are communicated to the membrane of the fenestra ovalis, and that the opening called the fenestra rotunda, closed by a similar membrane, is for the purpose not of receiving impulse from without but of yielding to that impulse from within. For example, if we suppose a bottle of water full to the lip, and a bladder drawn over it so that not a bubble of air is contained, although the water must be admitted to be compressible, an impulse upon the bladder would produce no such effect as would follow were there a hole covered with a bladder upon the side or bottom of the bottle; for then each impulse upon the top would be attended with a yielding of the bladder below and a consequent agitation in all the intermediate

'hus, it appears to us that the use of the fenestra
md its membrane is to give play to the membrane
enestra ovalis, and that without this provision,
there might be a general impulse communicated
luid in the labyrinth, like that communicated
the bones generally, there could be no wave or
m. If the shutting of the Eustachian tube, D,
, vol. ii.), so confines the *air* in the large cavity
mpanum as to render us deaf, what would be the
nce of the labyrinth (which contains *water*)
ut in on every side? The play, then, of the
the tympanum, and of the membrane of the
ovalis and of the fenestra rotunda, is not only re-
produce an undulation in the fluid within the
, but that undulation must take the particular
rough the scala of the cochlea, descending into it
ala vestibuli and ascending by the scala tympani.
ol. ii., page 37.) In this view it becomes inter-
consider the distribution of the nerve in the
since this internal part of the organ is so obviously
d with the finer exterior apparatus. We have
hat the nerve passes into the modiolus and extends
dge of the lamina spiralis, so that the sonorous
ns continued through these passages must affect
e on two surfaces; and whether we consider the
o be like the bending of the spiral turns of a
trument, or the fibres of the lamina spiralis to be
cession of chords diminishing regularly in length,
t least imagine that at one time the whole por-
ne nerve may be brushed and agitated, and that
r it may be partially affected.

rt, the concavities of the central cavity of the
, the vestibule, may produce an eddying of the
that the motion shall be concentrated to a point,
point there is seated a portion of the nerve; or
lation may pass round the semicircular canals
t the septum of each ampulla; or by being pro-
through the cochlea it may touch fibres of the
iralis of different lengths. All we mean to affirm

is, that there is so great an extent and variety in t
tribution of the acoustic nerve; and also in the cana
cavities, as fairly to give us reason for believing th
be the sources of that extensive scale, and of a
changes and combinations of sound which we
through this sense.

XXII.

OF THE CIRCULATION.

: animal body is attended with a never-ceasing · he whole framework. Not merely is there a)lood running in a circle, but all the things nto the composition of the animal body, solids luids, are under an influence that keeps them ; change. This, indeed, is the object or end ılation: for the blood contains in a fluid state omposed the solid framework. We might say id matter was resolved or melted, but that it is)n which thus reduces the texture to the con- fluid. At the same time that the blood con- has been the material of the body, it con-)f new matter, the product of digestion and ı, and which is destined to take the place of ıl that has been removed. The circulating us made the agent by which the revolution of ıimal frame as well as of the fluids is accom-

n by this, that there is nothing permanent in body. We see, and perhaps without much ıat a part cut heals, that a part excavated or is soon replaced, and in some of the lower .t members cut off are actually reproduced: all , but it requires fine experiment and accurate o enforce the conclusion that the animal body rowing, always forming; and that this inces- tion in the material of the frame is the grand between the living structures of the animal ıachinery. In the former there is a principle on incessantly at work, so that the action or

exercise is attended with no wear and tear, but,
contrary, the greater the activity the more perfe
structure, and what we term the healing process,
reproduction of parts, is the continuance of an
which has had no interval.

It being absolutely proved that there is nothing
manent in the body, we leave the reader to conside
question, which forces itself upon him, "What, the
it that gives identity? How comes the peculiarit
form and constitution and complexion to remain—or
does the memory serve us—when the material has b
many times removed?" But we have rather to consi
the grand operation by which these changes are wrou
—the circulation.

Modern chemists have estimated that 5208 grain
charcoal are thrown off from the blood in twenty-
hours, and this uniting with 13,392 grains of oxyge
the atmosphere that is breathed, constitutes, with a
proportion of caloric, the carbonic acid gas which i
charged from the lungs. Other secretions are also
posing of the material of the body; and although th
be necessary to health, it is the function of respira
which is the most directly necessary to life, and whic
guarded by pain and anxiety experienced the mom
that interruption is begun.

We may already comprehend how the blood flows
a great circle, taking up the material of the body by
absorbents and veins of the body, and throwing it off
the lungs: and how blood returning from the lungs,
rified by exposure to the atmosphere, comes back to
heart to complete its circle. We readily conceive
how this pure blood is necessary to all the vital op
tions, to the nourishment and growth of the body; bu
is not so easy to comprehend the manner in which
force of the circulation ever keeps pace with the co
tion of the body: active during the exercise of the bo
reduced and equable during repose; or how the b
generally will have the circulation moderate in deg
whilst an individual part being excited and in action
be accommodated with an activity of circulation ex

ned to the necessity for it. It is not possible, on
draulic principles, to explain how the blood shall
to the toes or ascend to the head by one im-
nd yet with a force exactly proportioned to the
and elevation of the member. Nothing is more
le than the manner in which the heart, as the
gine in the centre, has its irritability and power
united in close relation to the condition of the
If the pulse is to be felt by the physician, the
must recline, for if he stand up, on hydraulic
es a greater force is required to move the upright
of blood, and the heart beats more rapidly; and
pecially, is more remarkable, if the person be
nd weak. For the same reason no physician feels
e when his patient is anxious or perturbed, or at
must calculate on the pulse being accelerated.
nd many other examples might be brought to
at the circulation alters in correspondence with
tion of the body, and with its exercise; and that
with the emotions of the mind, as well as with
nges in the position and movement of the frame.
rn from this that the heart, through its sensibili-
the regulator of the circulating system, and that it
is purpose that it has such extensive sympathies.
emarks we premise as reminding the reader that
e more things to be admired in the contemplation
iving animal frame, than can be brought under the
the mechanism of the circulating organs, or the
ion of the tubes to the known principles of hy-
. It is, however, to these that we must now beg
ntion.

XXIII.

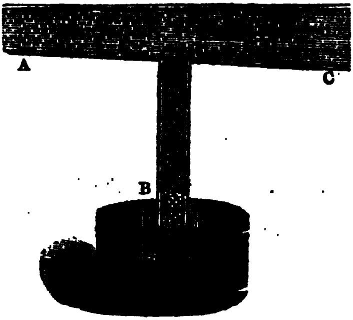
OF THE VEINS.

Our author has taken up the notion, which indeed is conveyed in anatomical books, that the veins are irregular in their form and course. We hold this to be a dangerous admission: first, because it leads to the supposition that there is a certain imperfection, and as it were negligence, in the structure of the frame; and secondly, because it induces the inquirer to be satisfied with a very superficial survey. The veins are considered as mere conduit-pipes, to carry back the blood from all parts of the body to the heart. But they are much more; they are reservoirs. Where could that large proportion of blood which is necessary, be deposited with more safety to life than in those recesses or interstices left by the bones and muscles of the body? But whilst this object is secured, another more important one is attained by the turning and twisting of the veins into the crevices and unoccupied spaces: for they become thus liable to be pressed by the action of the muscles; and so it comes about that the blood is permitted to move on slowly in these recesses whilst we lie inactive, but when we are aroused into action, it is pressed onward, the dimensions of the reservoirs are diminished, and the blood is accumulated upon the more active heart, and is ready to answer the demands of the system which that very activity requires. The sensations at the heart exciting the respiration, the chest is expanded, and the veins enlarged; and by the alternate suction and compression upon those great veins, the heart is liberally supplied. By this arrangement, then, there is ever a correspondence preserved between the activity of the body and the rapidity tion. For this is the sequence of actions—into activity; the blood, which was slowly is pressed forward to the heart: 2. The nded and excited: 3. The sympathy or bond ween the heart and lungs makes a call upon ry action; and the decarbonization of the place more rapidly: 4. The return of arterial he lungs to the heart is accelerated, and the tes the action of the arteries: 5. The in-ial action supports the exercise of the mus-; and, thus, there is a circle of relations rising out of that very seeming irregularity; their position and general condition ensure on of circulation corresponding with the ac-muscular system.

, that, in comparing the branching of the e arteries, there seems to be, as anatomists ains to show, an appearance of clumsiness rity in the former compared with the latter; e not inquired whether there was a reason ty—whether the distinction in the manner of joining a larger, accords with the direction n these tubes or not—and yet this is a ques-urally suggested, if we have a firm conviction atural body nothing is formed imperfectly, or Accordingly, it does appear that, in the dis-water-pipes, it is very necessary to attend to which a small pipe joins a larger. If a pipe o another contrary to the direction of the discharge into that lateral branch from the will not only be much smaller than what we te by the diameter of the tubes it should be, n circumstances it will discharge nothing at e water will be drawn from the lesser tube ter.

found that when a small tube, B, was inserted of a horizontal conical tube, A, in which the wing towards the wider end, C, not only did ape through the smaller tube, but water in a vessel, at a considerable distance below, was drawn up through the lesser tube into the greater.

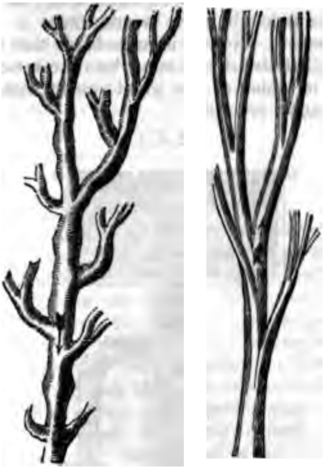
With these facts before us, we turn with interest to th curves of the arteries and veins, seeing that the contain fluids flow in the one from the trunk to the branch, in th other in an opposite direction from the smaller to th greater vessel.



And now, if, instead of taking the artery as the im-portant vessel, and the vein as less so—and therefo negligently contrived, we consider both of them to b important and perfect—we ought to expect that th course and curves should differ.

In the artery, where the blood is passing from the hea towards the extremities—that is, from trunk to branch— the branches slightly diverge from the direction of th stream in the trunk ; whilst the branch of the vein, whe the blood is passing from the lesser into the larger vessel, enters abruptly and at right angles. From this i appears, that if we could imagine such a malformation a that the offices of these vessels were changed, congestio would immediately take place, and the circulation coul not be carried on.

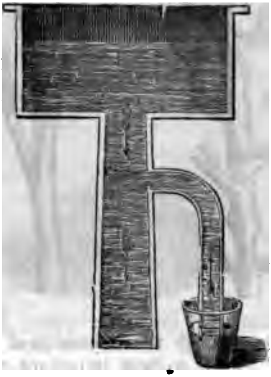
It appears, further, that if the veins were rigid, or placed in circumstances where their sides remained apart when wounded, instead of blood escaping, air might be



to them through the expansion of the chest in
g—and this is a most important circumstance;
such an accident takes place, death follows in-
ously. When a reservoir is emptied by a per-
ar tube, into which a smaller tube is inserted, the
scending by the larger tube, instead of escaping
esser, will draw the water up through that lesser
s to empty the glass in which its lower end is
d. By this we see that there may be points
des of tubes conveying fluid, in which the pres-
be negative; and we are made aware that the
ent in question, instead of being a negligent or
joining of the branch to the trunk, is, on the
a provision for the lesser tube entering at a
ngle into the side of the greater one.

tubes join to form a larger tube, and a hole be
the angle of their union, and if the water flow

from the lesser tubes into the greater tube, no wate
escape by the hole: in other words, there is a poi
negative pressure. Now it is remarkable that the ve
which are called absorbents enter into the venous s
at the angle of union of the great veins; that is, a
point of negative pressure.



XXIV.

ON THE ARTERIES.

erhaps no finer proof of the adaptation of the f circulation to the principles of hydraulics ct of the increasing diameters of the arteries ede from the heart. Mr. John Hunter took to prove this: and he did demonstrate that at artery divided into two branches, the united e branches were greater than the area of the t when the branches subdivided, the united subdivisions were greater than the areas of from which they were derived, and so on to e vessels. Reflecting on this, it is interesting t the engineer in laying down pipes comes to the conclusion, that a pipe dividing into two hose united areas are exactly equal to the area m which they proceed, will not deliver the ity of water that would have flowed through tube. He discovers that he must take into attraction and friction of the fluid upon the hat the smaller the calibre of the tube, the ttraction or friction will be proportionably the oes not this fact coming out in practice prove he united areas of the smaller branches of the arger than that of the trunk from which they ? If any further explanation be necessary it t the water flowing in a tube runs more ra- centre than at the sides—or, in other words, s a certain attraction or friction at the sides. s in standing by a flowing river; the friction r against the bottom and the sides retards the ilst *the velocity* of the current is greatest in the middle. As the water in the river is delayed at [illegible] bottom and sides, so is the fluid nearest the sides of [illegible] tube retarded by the friction between the fluid and [illegible] solid. Thus we see a remarkable coincidence between the increasing diameters of the circulating vessels, [illegible] of tubes laid down upon accurate hydraulic principles [illegible]

From the diameter of the arteries being larger [illegible] they recede from the heart, two advantages are [illegible] tained: first, that the blood is driven on with [illegible] ease; and secondly, that the extreme arteries [illegible] in some measure like the veins, reservoirs of blood. [illegible] man of middling stature has thirty-three pounds of [illegible] in his circulating vessels; and did the vessels not [illegible] as they receded from the heart, there would be no [illegible] for the deposit of this great quantity of blood.

We may venture upon some further illustrations.—[illegible] stream of water, unconfined, will take a very [illegible] form if falling by its own gravity from what it will [illegible] if forced in any other direction, by a *vis à tergo*. [illegible] water is poured out of a vessel it acquires velocity as [illegible] descends; the column is largest above and drawn [illegible] below, because it is increasing in velocity, and the stream that has a greater velocity must be smaller in diameter: but continuing to descend, the stream acquires such a degree of velocity that the atmosphere offers resistance, and then it again spreads out. But a column of water sent upwards as a *jet d'eau*, instead of contracting as it ascends, enlarges. The fluid is retarded as it mounts; and the stream being still propelled from below, it is forced between the filaments of the column above and disperses them, enlarging the column as it ascends and giving it a conical form. Hence it follows that if water is to be discharged from a reservoir along a horizontal tube, it will flow more rapidly if the tube be a cone, with its lesser end inserted into the reservoir; for the weight of the water in the reservoir still being a *vis à tergo*, and the stream from behind forcing itself between the filaments of the column and so dispersing them, it is clear that the increasing diameter of the tube *will* correspond with the natural enlargement of the

lumn of water, and give it an unimpeded exit. E
en, we have another explanation of the incre
meter of the arteries to receive the blood propelle
e heart.

In laying pipes for a *jet d'eau*, the ascent of the v
ll be diminished by any sudden angle in the tube ;
e *ajutage* must rise from the horizontal pipe wi
ntle sweep, or the jet will not reach so high as it o
do, from calculating the height of the water in
ervoir. This circumstance explains the parabolic c
hich the great artery takes in going off from the h
explains also why the branches of this great arter
at different angles, and why near the heart the br
es off at a greater angle from the direction of
eam.*

We have, perhaps, said enough to remove the n
hat there is anything like irregularity in the course
stribution of the vessels of the living body. But t
re some other laws of hydraulics which give intere
he structure and action of the circulating vessels.
elasticity of the coats of the artery is a subject of
portance in surgical pathology, and has very prop
been deeply considered. This power has not, how
met with sufficient attention as one of the forces pr
ling the blood.

The law of inertia is easily comprehended as it reg
solids. Every thing about us proves that it is more
cult to move a body at rest, than to accelerate it wh
has been put in motion. The same law holds of a col
of water in a pipe : it is easier to keep it in motion
to put it in motion from a state of rest. From th
follows that, in propelling water through a pipe
forcing-pump, as the impulse is given at intervals,
as the whole column is at rest after each stroke o
piston, much of the force must be lost. Now if
heart contracted and propelled the blood into the ar
and there was then an interval of rest, during w
blood was stationary, the next pulsation of

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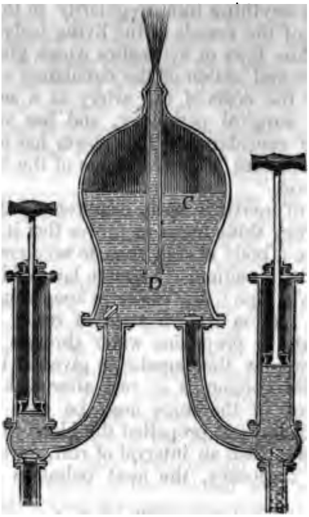
* This refers more especially to the intercost

would be in part at least exhausted in bringing the b
from a state of rest into a state of motion. This wil
best understood by following the successive contriv
which the engineer has employed, in raising wat
keep the column in motion uninterruptedly, and t
fore to use his power in accelerating the stream, r
bringing it from a state of rest into a state of m
The first idea was to have two forcing pipes inst
one, so that one stroke should succeed another w
interval. But it was soon discovered that there
difficulty in adjusting exactly the two forces; an
was found that three forcing-pumps were better tha
as more effectually providing against any interrup
the motion of the stream; the second filling up t
terval between the impulse of the first and third.



ı of the parts of the engine shows the desire
er to avoid interruption in the stream. But
› well illustrate our proper subject as the
n, which was to employ an elastic power;
neer contrived it thus:—A portion of air is
reservoir; the pipes of two forcing-pumps
ıto the reservoir, and they fill it half full of
e mouth of the pipe, D, which is to convey
er, reaches into the water in the reservoir.
rises, the air is compressed: so that, al-
pumps act alternately, the elasticity of the
acts uninterruptedly in pressing on the sur-
vater, and raising it by the tube, D, in an
m. The elasticity of the contained air fills
al between the actions of the pumps, and
interruption to the force with which the
elled upwards.

se are sufficient indications of the necessity
ers acting in propelling the blood from the
first is a sudden and powerful action of the
ıe second is a contraction of the artery,
nilar, excited by its distention: the third,
perty independent of life, is a power per-
ıterval or alternation; it is the elasticity of
the artery: and these three powers, duly
p up a continued stream in the blood-vessels.
ıat when an artery is wounded, the blood
es; but that proceeds from the regular ac-
a jet which yet has no actual interruption.
ıis continued flow of the blood provided,
be a loss of power, at each pulsation of the
ying the blood from a state of rest to a state
ınd if we consider how many pulses there
enty-four hours, 80,000, we may make some
he loss of vital power that would accrue had
neglect of the law of inertia in the apparatus

XXV.

MICROSCOPIC PHENOMENA IN THE ANIMAL BODY—MOLECULAR MOTIONS—CILIARY MOTIONS.

We have noted the judicious course pursued by Dr. Paley, in preferring the proofs of design drawn from the structures of our bodies, which secure our existence, or minister to our comforts or enjoyments; for in these there may well be perceived the object of the provisions, and the mode by which they are attained; and this supports us in a due estimate of ourselves,—seeing that there is so much care of us, and that our bodily and intellectual endowments have so many relations to the system of nature. By the aid of the telescope or microscope we are equally carried, as it were, out of ourselves, to view nature foreign to us. If, it has been justly observed, in contemplating the heavens with minds ill confirmed as to the intentions of Providence towards us, the study is far from being consolatory, the same may be said of the microscopic world. The discovery of the universal prevalence of life, of animals within animals, of the inhabitants of a drop of fluid as difficult to enumerate or arrange as those of the ocean, gives rise to thoughts which do not flatter our self-importance, more than the contemplation of the magnitude of the heavenly bodies, and the extent of space through which they range. It will, therefore, be tending to the object of this volume to show that with the microscope, that is, by observing the atoms of our frame which are invisible to the naked eye, we discover motions and actions, both of inorganic and animated particles, which tend to the preservation of life, and to the performance of the offices in the animal economy, fully as remarkable as the contractions of the *heart*, or the play of the lungs.

It will be necessary to the correct estimate of the facts which we have to mention, that we advert to a curious discovery of Mr. Brown, relative to the motions of inorganic molecules. This gentleman's celebrity is of a kind which may not readily be comprehended by some readers; for his retired and philosophical habits cause him to occupy a small space in society at home, in comparison with that reputation which extends wherever science is cultivated. He was directed to this subject by a motion visible in the pollen of plants, when under his microscope, which led him to further investigations; and he found that when inorganic as well as organic bodies were minutely divided, and floated in a drop of water, active motions were seen in the molecules. The motions of these particles are different from those of animated matter. The molecules are spherical, and between 1-20,000th and 1-30,000th of an inch in diameter. I have myself seen these, and nothing can be more surprising than their evolutions, like figures in a dance, apparently produced by the attraction and repulsion of the particles themselves. It might be supposed that the rapid evaporation from the surface of the drop would produce eddies within it, and that these molecules were carried by the circulation of the fluid; but the ingenious mode by which Mr. Brown prevented the evaporation of the watery particle, by surrounding it with oil, whilst the motions of the molecules continued, refutes this hypothesis, and inclines us the more to rejoice that the curious phenomenon was discovered, not accidentally, but by a philosopher.

Indeed, whilst looking upon these molecules, we are surprised by bodies, obviously animalcules, jostling them, and darting across the field of the microscope; and the natural reflection is, how much more minute must the constituent parts, or molecules, of these animalcules be! Their motions are not fortuitous, or owing to any polarization or influence external to them, as galvanism or magnetism: they have instincts and appetites, and are susceptible of excitement: their bodies are nourished by digestion, or *imbibition:* they have circulation, though

it may be with a different apparatus from that of l
animals: their circulating fluids, their containing s
their apparatus for motion, imply that the ultimate
cules of their composition must be infinitely small,
in comparison with the minute particles which w
contemplating: and this we state, to do away with
speculations which men are prone, to indulge in,
they suppose that they have at last attained a sig
these active molecules, of the ultimate particles
constitute the frame-work of animals.*

Another class of facts drawn from the minute
is no less wonderful than the motion of these "
molecules:" we allude to certain vibratory motio
as they are termed, *ciliary* motions, on the muco
faces of animals. They are somewhat analogous
actions of the rotatory apparatus of some of the inf
Both the respiration and the prehension of food i
animals are accomplished by an influence of their
whereby a current is kept up in the surrounding
a fresh stream by this means plays over the appa
their respiratory organs, whilst in some the minut
ticles of nutritious matter in the fluid are brought
tact with their prehensile organs.

The soft aquatic animals, called porifera, have
orifices on their surface, into which the surroundin
is drawn, and being then brought into a common
is expelled through a larger central mouth.† W
conceive an action of these pores, by which the
may be sucked in and propelled; but the more
action is that of the cilia, or filaments, with whic
tentacula are covered. These cilia have a motion
produces a vortex in the fluid, and tends to conv
floating nourishment towards the mouth.‡

This well-attested fact leads us to comprehe
phenomenon which is the principal object of thi

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[*] Animalcules are visible in the microscope, so s
is estimated that a million of them do not exc
de.

[†] Spallanzani.

:xplains what is meant by "ciliary motions." It is
necessary to mention that what anatomists term the
us membrane is the lining of all those tubes and
ies of the animal body which open outwardly, in
adistinction to the membranes which line the pro-
:avities of the body, and which are called serous
branes. It is of itself a circumstance tending to the
ort of the conclusions to which the whole arguments
s book point, that the fluids thrown out to lubricate
surfaces are various and appropriate to the nature
e cavity. The membrane which is continuous all
d, and has no outlet, must be moistened by a fluid
ı is to be absorbed again; but the surface of the
7 which has an outlet is moistened by a fluid which
be discharged as from an emunctory.

is brings us to the fact above referred to, which, if
bservation has been correctly made, is by much the
extraordinary in the whole animal economy.* A
on of the mucous membrane of an animal recently
l is placed, with great nicety, under the field of the
scope, and in water: some fine particles, which will
in the water, are then added. What has been used
most advantage is the black pigment of the eye,
h is easily diffused, and the particles of which are
minute. The experimenter is here cautioned to
iguish the molecular motions discovered by Mr.
n, from those now to be described. A rapid vibra-
motion is to be seen on the surface of the membrane,
hese motions produce a current in the fluid in contact,
h is made apparent by the floating of the minute
cles of the pigment. The remarkable part of this
omenon is the direction of these currents. The cilia,
nall filaments projecting from the membrane, move
ch a manner that the current is always directed to-
s the outlet of the cavity or tube; and thus it is
ctured that a new source and kind of action, inde-
ent of muscularity (that is, the irritability of the
er muscular fibre), is provided for the gradual and

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* First observed by Purkinje and Valentin.

regular ejection of the secretions from these tube cavities which enter deep into the animal structure this country these extraordinary endowments of the surface are under the examination of one* who wil secute the subject with philosophical precision, an result of whose inquiries may be expected with an rest proportioned to the important nature of the fa

[*] Dr. Sharpey, of Edinburgh.

XXVI.

ON LIFE.

we survey the discoveries in the physical and ab- sciences, our wonder and admiration are excited grasp and various powers of the human mind; learn, also, that men acquire a habit of viewing , and of thinking, which trammels them, though ed of the highest genius, when they change ab- the subject of their studies.

life of the body is a study new to science, and it natural alliance with any of the higher branches occupy men of intellect; yet it requires a great of thought. Those who follow intricate mathe- deductions, calculate the return of comets, esti- e magnitude and attraction of the sun and planets, n extend their investigations to the fixed stars, the subject as much under the influence of habit rtisan who tries to accomplish by the dexterity of d, that for which a different manner of working has l him. This may be a humiliating consideration, nust be acknowledged, or we shall never discover t hypotheses we have hitherto been misled; nor be directed in a course of observation likely to e the science of Life.

chemist is in the habit of observing the laws of e powers, of elective attraction, of heat, and of al, or galvanic, or magnetic influences. He makes from the observation of the mere ponderable and qualities of matter, to the study of laws which that which can neither be weighed nor confined; should imagine, therefore, that the process of his ng would prepare him for comprehending more he influence of life, as exhibited in the phenomena of the animal body. But it has been far otherwise. The chemist, when he commences the study of physiology, instead of pausing and considering that he is about to enter on a new region, where phenomena unexampled before are to be presented to him, or are to be seen through different media, and the forces estimated by different means, carries along with him habits of thinking which promise no improvement in this new field; and coming encumbered with all his apparatus, proceeds t measure that property which gives sensibility, motion and thought, by the instruments he has hitherto employe in marking the current and force of electricity; and regards the brain as no more than an electric pile discharging at intervals along the nerves the fluid successively developed. Such are the false analogies whic satisfy ingenious minds, so that they cease from inquiry and leave science stationary. The mathematical an mechanical physicians long retarded the true knowledg of physiology; and we are now nearly as much embarrassed by the fashion of the day, of applying, to investigate the laws of life, the mode of reasoning which ha been successful in the chemical sciences. There are bu two men who have enlightened us on the doctrine of th life of the body, Haller and Hunter—and this is, in othe words, saying, that it is altogether a recent science.

It is necessary to premise thus much, that the reade may not feel disappointment, if he fail, at first, in attemp ing to comprehend the subject. What does he unde stand by life?—That intelligence, feeling, and motio which he sees manifested in the animal body. If, in th understanding of the term, he hears that Mr. Hunter di covered that there was life in the blood, it is possible th he may receive the announcement with the same ridicu with which the world at first heard it. But let us s how the subject opened upon Mr. Hunter's mind. H was engaged in minute inquiries into the gradual dev lopment of the chicken in the egg. On breaking one eg it was found perfectly sweet; the next was in a high sta of putrescence. What, then, was the difference of the condition? Now let us not confound this question wi what is termed organization. The chick at this time is concealed within a vesicle not larger than the head of a pin. It is the white and yolk of the egg that we are examining. Here is no heart, or vessels, or brain, or nerves, or anything of an animal body. The question of organization, then, is put quite aside. Nevertheless, Mr. Hunter conceived that the difference between the putrid and the sweet egg depended upon the influence of life, which in the latter counteracted the chemical affinities, and prevented the matter from falling into a putrescent state. If then, said he, the matter of the egg has that property of life to check and control the affinities which all matter divested of life is subject to, has it also the power of resisting the changes of temperature? And now, upon comparing the putrid and the living egg, he found that the latter resisted freezing; and he thus showed that the property which resists putrefaction is allied to the property of the animal body which preserves it in a uniform heat, though exposed to the changes of temperature in surrounding bodies. We see by this that a portion of matter in an egg, or in a seed, shall be endowed with a principle, which, however obscure, we perceive by its effects.

Thus, living matter is under the influence of laws totally distinct from those which govern dead matter. What shall we call this peculiar property? We have acquired a notion of life by witnessing the effects of many causes combined in the whole animal. Motion is in general the result of these; and so we associate life and motion. Mr. Hunter showed that each part of the body which possessed life exhibited it by different phenomena. He said truly, that when the muscle cut off from the animal recently killed still palpitated, it was by its property of life. Accordingly, when a portion of the blood was withdrawn, he observed that it exhibited properties totally different from dead matter: it was drawn a fluid; and this fluid presently coagulated. What, said his opponents, is there in this? Do we not see a fluid jellying, and becoming solid; and is this to be a proof of life? But Mr. Hunter demonstrated that the coagula-

as not in any respect like the forma-
at heat neither accelerated nor pre-
took place whether the fluid was left
that nothing prevented the blood be-
the contact and influence of the living
ody. He showed, also, that the blood
ed of life or killed, and then it no longer
short, he compared this property of co-
blood to the contraction of the muscle;
her remarkable properties in the blood, he
e coincidence, that when a man was killed
the muscle did not stiffen in death, that is,
tract, neither did the blood coagulate.
step of Mr. Hunter was to combat those
epresent the body as bearing a resemblance
y moved by a weight. In the machine, he
eight of the jack-stone is conveyed from one
other, and from one wheel to another; but
ere in this analogous to motions of the living
Take away one of these wheels or levers, there
erty or power in it; take a part of the body,
s life, not as a property common to all the body,
of gravitation in dead matter, but each portion
endowment of life which is demonstrable or evi-
distinct phenomena: and then he adds, true it is,
ere is the example of beautiful machinery in the
body, but how much more admirable are the dif-
endowments of life which, corresponding together,
er to the intellectual being! One part has the pro-
of receiving impression, another has the property
nsmitting it, though it could not receive it. The
thus approached and influenced, gives out its man-
by cords totally distinct, and with different proper-
: these have no motion in themselves, but they
nge and control the moving organs of the body, which
e locomotion and agency. The whole body, then, i
ollection of parts, possessing different endowments
e, exhibiting, by different phenomena, the presence
life; and these different endowments have a beari
or a systematic arrangement, by which

nication is established between the mind and the
ıl and material world.

Hunter illustrated the subject thus:—Death is
nt or real. A man dragged out of the water, and
ɜarance dead, is, notwithstanding, alive, according
lefinition we have given. The living endowments
individual parts are not exhausted. The sensi-
nay be yet roused; the nerves which convey the
sion may yet so far retain their property, that other
nerves may be influenced through them; the
s may be once more concatenated, and drawn into
.taneous action. That vibratory motion which we
ıst said may be witnessed in a muscle recently cut
the body, may be so excited in a class of muscles,
mple in the muscles of inspiration, that the appa-
dead draws an inspiration. Here is the first of a
ɔf vital motions which excites the others, and the
ɪeats, and the blood circulates, and the sensibilities
tored; and the mind, which was in the condition
asleep, is roused into activity and volition, and all
nmon phenomena of life are resuscitated. Such is
ies of phenomena which is presented in apparent
rom suffocation; but, if the death has been from
ry of some vital part, the sensibilities and proper-
action in the rest of the body, though resident for
have lost their relations, and there is a link want-
that chain of vital actions which restores animation.
then, there can be no resuscitation; and the death
individual parts of the body rapidly succeeds the
nt death of the body.

ɔerceive now that our original conception of life and
ms we use respecting it, in common parlance, are
adapted to this subject when philosophically con-
l. We early associate life and motion so intimately
e one stands for the other. If we then investigate
tomy, we find a curious and minute mechanism in
on, an engine and tubes for circulation, and, in
an internal motion of every particle of the frame;
ɜ anatomist is also led into the error of associating
nind life with motion and organization. But when

we consider the subject more closely, and divest our of habits and prejudices associated with words, we ceive that, without making any vain and even dan attempt at definition, life is first to be contemplated peculiarity distinguishing one of two classes into all matter must be arranged: the one class, whic braces all living matter, is subject to a controlling ence which resists the chemical agents, and prod series of revolutions, in an order and at period scribed; the other, dead matter, is subject to laps change under chemical agency and the common l matter.

Let us examine the body of a perfect or a compl animal. We find each organ possessed of a di power. But there is as yet no conventional lan adapted to our discourse on this subject, and that source of many mistakes; for when a man even lik Hunter had his mind illuminated upon this science was he to frame his language, when every word t used had already a meaning which had no referen the discovery he had made—to the distinct qualities he had ascertained to belong to the living parts?

The progress of science in the present day, alt it does not bring us nearer to the comprehension nature of life, yet furnishes us with such analog enable us more easily to comprehend how this pri may be combined with the material of an animal and yet be perfectly distinct from it. The disco which have led to the atomic theory, and to that molecules of bodies being under a polaric influence, us with the impression that the minute particles of mon matter (in contradistinction to living matter under an influence which may be bestowed or withd that as the index of the compass points to the north property of the metal itself, but through an infl given to it and existing around it, so do the most m particles of bodies arrange themselves by some suc peradded influence, and partake of polarization. If, according to the prevailing opinion of philoso everything we touch, or see, or taste, all matter, in ts qualities arising from the arrangement of par- infinitely minute, and that arrangement resulting in influence exterior to them, or superadded to them, t not facilitate our conception of a power or pro- bestowed on what is termed living matter and yet ially distinct? The difference between dead and matter will then appear to be, that in the one in- the particles are permanently arranged and con- to exhibit their proper character, as we term it, by ingenuity and practice some means are found to raw the arranging or uniting influence; and then atter is chemically dissolved—resolves into its ele-, and forms new combinations: whilst the life con-, not simply to arrange the particles, and to give the order or organization of the animal body, but irl them in a series of revolutions, during all which aterial is passive, the law being in the life. The and succession of these changes and their duration t result from the material of the frame, which is the in all animals, but from that influence which we term nd which is superadded to the material.

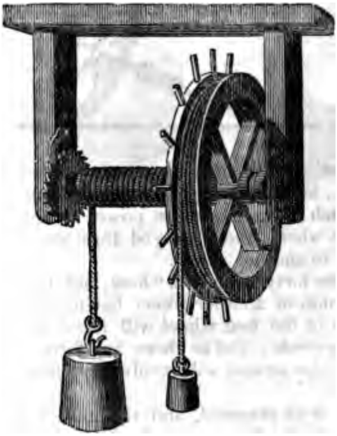
XXVII.

ILLUSTRATION OF THE WORKS OF A WATCH.

(See beginning of Chap. I.)

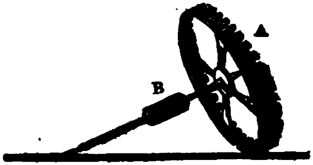
MANY, perhaps most, persons carry watches, witho ever thinking how such pieces of mechanism become a measure of time. This incurious habit is hurtful, for i may prevail to the neglect of other objects. We mu suppose such persons to be quite indifferent to the struc ture of their own frame, by which they move and hav so many enjoyments. The subject forms a good less in mechanics for a youth. Let him look into his watch, and learn how the wheels act, and how all are regulat by the balance, to measure time.

When men are advanced in science, they have sometimes little objection to see the particular subjects of their study involved in mystery. They are apt to deliver things in the form of a paradox. Thus they will affirm that the power of the hand, exerted through a machine, may raise a weight of many stones, and that one pound may weigh up one hundred. We are entitled to say, that the thing is impossible as the mechanist literally states it; that the props of the machine, the centre o the levers and the axles sustain by much the greater portion of the weight; and that the power of the hand is only given in addition to a weight which, though sm has, by the distribution of the force on the fixed poi of the machinery, become balanced against the gre ht to be raised. This is obvious in the simplest f chine, *the wheel and axle*, when we see it at r lesser weight balancing the greater. In and the greater weight are d rest on the beams which lesser body the *power*, and the greater body ; and the motions of these will be in propor- ieir distance from the centre of the axle. ly, we may measure the space through which , by pulling on the lesser weight, and seeing of the rope is uncoiled in one revolution of the l comparing that with the length of rope coiled the axle in the revolution, and consequently esponding time.



h is an instrument where a set of wheels are evolve with a uniform velocity, and at a certain to become the measure of time. When this obtained, an index, or hand, is put on the axis these wheels, and thus made to revolve on a e the fractions of the revolution are marked. ore hands may be applied to different wheels, will indicate the subdivision of time in which l wheels revolve in a minute, an hour, or in urs.

In this figure, A is the wheel, and the notche rather the projecting points on it, the *teeth*.* B i *pinion*, and the teeth on it are technically *called leaves*. This is the wheel and pinion, and we perc the resemblance to the wheel and axle. The teet the wheel move with a rapidity in proportion as the cumference of the wheel is distant from the axis or ce of motion.



The wheel and pinion may be used either to ac rate motion, as when the power is applied to the pi or to diminish it, as when the power is applied to teeth of the wheel, and conveyed through the leav the pinions to another wheel.

If there be forty teeth in a wheel, and this wheel into the pinion of another wheel having ten leaves of the teeth of the first wheel will cause the secon complete its circle; and as there are forty teeth in first wheel, the second will revolve four times for o the first.

If things were reversed, and the motion comme in the second wheel, so as to be communicated to first, the mechanism would then have the effect o minishing the motion to one quarter. In both ways are the wheel and pinion employed in the wat

The power moving the wheels of a watch is

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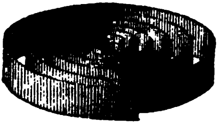
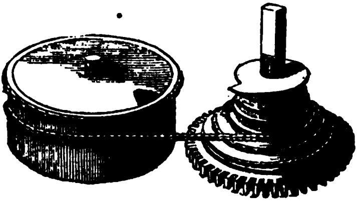
* The resemblance in these teeth to the jagged edge spur explains why certain wheels are called the "*spur-g* The engraver has here substituted, for my sketch, a c wheel, that is, one where the teeth stand on the edge circlet, and parallel to the axis.



g; it is here represented relaxed, as when t
h is run down.



the left hand of this figure we have the *barrel*, a
drical box, in which the spring is coiled; and the
nity of the spring in the centre of the coil being
to an axle in the centre of the barrel, while the
extremity is attached to the inner circumference
barrel by a steel pin, the barrel must thus turn
s the spring uncoils.

pyramidal body on the right is the *fusee*. In
up the watch, the key is fixed on the pivot of
y, turns the fusee, and through the chain which
o the barrel the barrel is also turned round, and
g within wound close up to its axle. When
is removed, the spring acts, the barrel slowly
and the chain, wound upon the barrel and
n the fusee, turns the fusee round. On the
s body we observe the spur teeth of a wheel.
l is the source of all the movements in the

t not neglect to observe a pretty contrivance
mechanical power of the fusee correspond

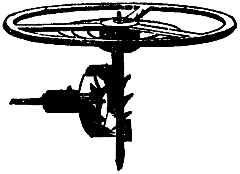
with the diminished power of the spring as *it uncoils*. The spring exerts the greatest force when it begins to uncoil itself, and this force is diminished as it relaxes. To correct this inequality the fusee is formed. It is an axle so contrived that, with the varying power, the motion shall be uniform, and for this purpose it has the form of a truncated cone with a spiral groove which receives the chain. When the spring is acting with the greatest intensity, the chain pulls on a part of the fusee, not much removed from the centre of its revolution, and therefore with a small leverage; but when the spring acts feebly, as the spiral groove becomes farther and farther removed from the axis of the fusee, the chain is uncoiled from it with a greater lever power.

The great wheel on the base of the fusee checks into leaves of the pinion of the second or central wheel, and that moves, in succession, the third and fourth wheels. But before we estimate the effects of the respective wheels and pinions, we shall pass to the scapement, or balance.

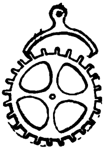
The effect of the scapement is to preserve the moving power, or "sustaining force," uniform, to equalize the effect of the spring on the work; for although this is in part effected through the fusee, it is not done sufficiently.

It is interesting and improving to observe, in the history of philosophy, how occurrences the most familiar become important when applied by genius to the arts. If a bell-rope hang free, and especially if a weight be appended to it, it will swing a long time. If we should chance to note the regularity and time of its motion, and so leave it, on returning, if it move at all, its motion from side to side (or its oscillation) will be performed in very nearly the same time as at first. Familiar and simple as this is, it is the *pendulum*, and the measure of time; and we can easily comprehend that if a rod, thus swung, be so appended to the work of a clock, as to receive a slight impulse, sufficient to keep it in motion, it will re-act on the clock; and if the motions of the *wheels be nearly* in accordance with the oscillation of ıdulum, it will preserve the motion of the whole ɜry correct.

rdingly it is easier to make a clock than a watch; watch some substitute for the pendulum must be and the substitute is a very delicate piece of alled the *scapement*.



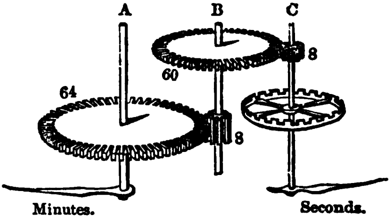
upper wheel here is the balance-wheel, within ı fine hair spring is coiled. This spring is alter- pulled and let go by a motion communicated to eel; and the spring, by the regularity of its mo- nswers the purpose of the pendulum. The notched below is the scapement-wheel; two projecting on different faces of the axle of the balance-wheel ɹuccession between the teeth of the scapement- when one of these slips off the teeth, and the set free, the spring recoils, and delivers the other nto the succeeding notch: and thus the regular of the spring, without stopping the revolution of pement, regulates the time in which the teeth are ɜe, and by this means equalizes the motion of all eels.



ɜ is another form of the scapement-wheel. Call ɹer part the *crutch*, the lower the scapement-wheel.

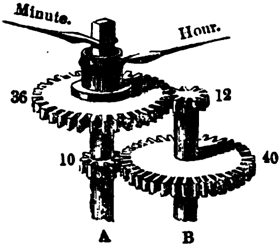
The sustaining force, which, in this instance, is the spring, operating through a succession of wheels, throws out the pallet of the crutch from the tooth of the scapement: in doing this the teeth act against a hair spring, which, by its recoil, places the pallet in the succeeding notch. By this contrivance the regular motion of the hair spring corrects the lesser deviation in the motion of the wheels which might otherwise arise from the imperfection of the workmanship. The balance-wheel and spring move with a quickness which permits the scapement-wheel to beat 18,000 times in an hour—the common rate of a watch that shows seconds.

Having seen how the motions are regulated, we may consider the rate of revolution in the wheels, according to the number of leaves in the pinions, or of the teeth in the circumference of the wheels. The central wheel, A, that which is moved by the fusee, has sixty-four teeth; these fall into the pinion of the third wheel, B, which has eight leaves, the wheel itself having sixty teeth; these sixty teeth play into the pinion of the fourth wheel, C, which has eight leaves. The central wheel going round once in the hour, the fourth wheel will go round sixty times in an hour, and with the hand attached to its axle it will mark seconds. This will be more easily understood by a reference to the sketch. The wheel on the axis, A, to which the minute-hand is attached, turns round once in an hour. Its sixty-four teeth play upon the pinion on the axle, B; as this has eight leaves, it

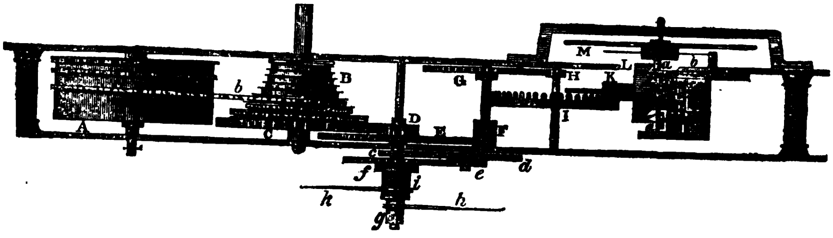


will revolve once for every eight teeth of A, and consequently eight times during the whole revolution of A, that is, in an hour. The wheel on the same axle, B, has sixty teeth, which turn the eight-leaved pinion of C; it will, therefore, turn the axle, C, seven times and a half (for $60 \div 8 = 7\frac{1}{2}$) during one revolution, or sixty times during the eight revolutions which B makes in one hour.

Thus we have the minute-hand and the second-hand measuring minutes and seconds of time on the dial; but we have not yet the hand which shall go round in twelve hours and mark the hours on the dial. To effect this the same machinery is used: viz., the wheel and pinion; but the moving power is applied so as to diminish the rate of motion—that is, by making the force act from the leaves of the pinions to the teeth of the wheels, instead of from the teeth to the leaves.



We may remember that the centre wheel, A, goes round once in an hour; that the axle of this wheel passes through the dial and has the minute-hand attached to it. The pinion of this wheel, called the *cannon pinion*, has ten leaves, which play, during the hour, upon a wheel, B, having forty teeth, which accordingly is moved round only once in four hours. This wheel, B, has a pinion of twelve leaves working into a wheel of thirty-six teeth, and *must therefore* make three revolutions to cause that



Description of the Engraving.

A, the barrel; B, the fusee; b, a flexible steel chain which communicates the motion of the barrel to the fusee; C, the great wheel; D, the pinion (called the cannon pinion) of the second or centre wheel, designed to revolve once in an hour; E, the centre wheel, containing sixty-four teeth; F, pinion of the third wheel, containing eight leaves; G, third wheel, containing sixty teeth; H, pinion of fourth wheel, containing eight leaves; I, fourth wheel, containing sixty teeth; K, pinion of the balance wheel (sometimes called the scapement wheel), containing six leaves; L, the balance wheel, containing fifteen teeth, which operate upon the pallets of the balance, and give to it its oscillating motion; *a a*, the pallets; M, the balance; *b*, the hair spring; *c d e f*, minute wheels; *e*, pinion of ten teeth, revolving once in an hour; *d*, wheel of forty teeth, revolving once in four hours; *e*, pinion of twelve leaves; *f*, wheel of thirty-six teeth, revolving once in twelve hours; *g*, the end of the axis of the centre wheel upon which the minute hand *h* revolves; *i*, the axis of the hour wheel upon which the hour hand moves round once in twelve hours.

revolve once. But as the former, B, requires four hours for one revolution, it must occupy twelve in making three: and consequently the thirty-six toothed wheel will take twelve hours to complete one. To its axle, therefore, the index is attached, which we call the hour-hand of the watch. The axle is a cylinder which incloses the axle of the minute-hand, so that both revolve, indicating the hours and minutes on the same circle of the dial.

It has taken some hundred years to perfect a common time-piece, and the account of the successive improvements is very curious.

In conclusion, we perceive the dependence of the wheels of a watch upon each other; they are nothing singly; they have no energy inherent in them. In the animal frame it is otherwise; each distinct portion has a quality belonging to it, which stands in relation to the quality of some other part.

Were any property different from that of form, which gives the mechanical power, possessed by part of the watch, it might derange the movements. It would be foolish to imagine any endowment like that of life, but we may suppose some such property as polarization, or magnetism, added to a wheel or lever: what could result but disturbance of the mechanical adjustment? We take the following felicitous example:—

A watchmaker had put into his hands a time-piece; but notwithstanding the excellence of the workmanship, it went irregularly. He took the work to pieces and put it together twenty times: no defect could be discovered, and yet it was imperfect,—it was a bad watch! At last, it occurred to him that the defect must be in the balance-wheel (which we have seen to be the regulator of the watch); he thought it possible that this part had become magnetized, and on applying a needle to it he found his suspicion true. By coming accidentally into contact with a magnet, the metal of the balance-wheel had acquired an attraction for the steel work of the watch. A *property*, superadded to a part of the watch, and at variance with the principle of mecha on which the machinery was constructed, thus deran the whole.*

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* We have taken the illustration from Cecil's 'Remai as quoted by Dr. Latham in his Lectures. The author it to explain the effect of a certain bias or predilection in mind, which deranges the otherwise sound reasoning.

ANIMAL MECHANICS,

OR,

ROOFS OF DESIGN IN THE ANIMAL FRAME.

BY SIR CHARLES BELL.

LISHED UNDER THE SUPERINTENDENCE OF THE SOCIETY
FOR THE DIFFUSION OF USEFUL KNOWLEDGE.

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PART I.

:RFECTION OF DESIGN IN THE BONES OF THE HEAD, E, AND CHEST, SHOWN BY COMPARISON WITH ARCHI- :URAL AND MECHANICAL CONTRIVANCES.

INTRODUCTION.

ɜpare us for perceiving design in the various in- structures of an animal body, we must first of all that perfect security against accidents is not con- with the scheme of nature. A liability to pain jury only proves how entirely the human body is l with reference to the mind; since, without the ɹed call to exertion, which danger and the uncer- of life infer, the development of our faculties be imperfect, and the mind would remain, as it uneducated.

: contrivances (as we should say of things of art) ɔtecting the vital organs are not absolute securities t accidents; but they afford protection in that measure or degree calculated to resist the shocks ·essure to which we are exposed in the common ıstances of life. A man can walk, run, leap, and because the texture of his frame, the strength and of his limbs, and the specific gravity of his body, relation with all around him. But, were the ɔhere lighter, the earth larger, or its attraction –were he, in short, an inhabitant of another planet, would be no correspondence between the strength, y, and muscular power of his body, and the ele- around him, and the balance in the chances of life be destroyed.

thout such considerations the reader would fall into the mistake, that weakness and liability to fracture imply imperfection in the frame of the body, whereas a deeper contemplation of the subject will convince him of the incomparable perfection both of the plan and of the execution. The body is intended to be subject to derangement and accident, and to become, in the course of life, more and more fragile, until, by some failure in the frame-work or vital actions, life terminates.

And this leads us to reflect on the best means of informing ourselves of the intention or design shown in this fabric. Can there be any better mode of raising our admiration than by comparing it with things of human invention? It must be allowed that we shall not find a perfect analogy. If we compare it with the forms of architecture—the house or the bridge are not built for motion, but for solidity and firmness, on the principle of gravitation. The ship rests in equilibrium prepared for passive motion, and the contrivances of the ship-builders are for resisting an external force: whilst in the animal body we perceive securities against the gravitation of the parts, provisions to withstand shocks and injuries from without, at the same time that the frame-work is also calculated to sustain an internal impulse from the muscular force which moves the bones as levers, or, like a hydraulic engine, propels the fluids through the body.

As in things artificially contrived, lightness and motion are balanced against solidity and weight, it is the same in the animal body. A house is built on a foundation immoveable, and the slightest shift of the ground, followed by the ruin of the house, brings no discredit on the builder; for he proceeds on the certainty of strength from gravitation on a fixed foundation. But a ship is built with reference to motion, to receive an impulse from the wind, and to move through the water. In comparison with the fabric founded on the fixed and solid ground, it becomes subjected to new influences, and in proportion as it is fitted to move rapidly in a light breeze, it is exposed to founder in the storm. A log of wood, or a Dutch dogger almost as solid as a log, is comparatively safe in the trough of the sea during a storm—when a bark, slightly built and fitted for lighter breezes, would be shaken to pieces: that is to say, the masts and rigging of a ship (the provisions for its motion) may become the source of weakness, and, perhaps, of destruction; and safety is thus voluntarily sacrificed in part, to obtain another property of motion.

So in the animal body: sometimes we see the safety of parts provided for by strength calculated for inert resistance; but when made for motion, when light and easily influenced, they become proportionally weak and exposed, unless some other principle be admitted, and a different kind of security substituted for that of weight and solidity: still a certain insecurity arises from this delicacy of structure.

We shall afterwards have occasion to show that there is always a balance between the power of exertion and the capability of resistance in the living body. A horse or a deer receives a shock in alighting from a leap; but still the inert power of resisting that shock bears a relation to the muscular power with which they spring. And so it is in a man: the elasticity of his limbs is always accommodated to his activity; but it is obvious, that in a fall, the shock, which the lower extremities are calculated to resist, may come on the upper extremity, which, from being adapted for extensive and rapid motion, is incapable of sustaining the impulse, and the bones are broken or displaced.

The analogy between the structure of the human body and the works of human contrivance, which we have to bring in illustration of the designs of nature, is, therefore, not perfect: since sometimes the material is different, sometimes the end to be attained is not precisely the same; and, above all, in the animal body a double object is often secured by the structure or framework, which cannot be accomplished by mere human ingenuity, and of which, therefore, we can offer no illustration strictly correct.

However ingenious our contrivances may be, they are not only *limited, but they* present a sameness which becomes tiresome. Nature, on the contrary, gives us th same objects of interest, or images of beauty, with su variety, that they lose nothing of their influence a their attraction by repetition.

If the reader has an imperfect notion of design a providence, from a too careless survey of external natu and the consequent languor of his reflections, we ho that the mere novelty of the instances we are about place before him may carry conviction to his mind; we are to draw from nature still, but in a field which been left strangely neglected, though the nearest to of all, and of all the most fruitful.

Men proceed in a slow course of advancement architectural, or mechanical, or optical sciences; when an improvement is made, it is found that ther all along examples of it in the animal body, which o to have been marked before, and which might have gested to us the improvement. It is surprising tha view of the subject has seldom, if ever, been taken ously, and never pursued. Is the human body fr by an all-perfect Architect, or is it not? And, question be answered in the affirmative, does it no proach to something like infatuation, that possessin perfect models as we have in the anatomy of the we yet have been so prone to neglect them?

We undertake to prove, that the foundation Eddystone lighthouse, the perfection of human tecture and ingenuity, is not formed on princi correct as those which have directed the arrangem the bones of the foot; That the most perfect pi kingpost is not adjusted with the accuracy of the l bones which support our weight; That the insert a ship's mast into the hull is a clumsy contrivance pared with the connexions of the human spin pelvis; And that the tendons are composed in a n superior to the last patent cables of Huddart, or t more recently improved chain-cables of Bloxam.

Let us assume that the head is the noblest part let us examine the carpentry and architectural cc *ances* exhibited there.

nt, before we give ourselves up to the interest of
subject, it will gratify us to express our conviction,
the perfection of the plan of animal bodies, the de-
stration of contrivance and adaptation, but more than
e, the proof of the continual operation of the power
h originally created the system, are evinced in the
erty of life,—in the adjustment of the various sensi-
ies,—in the fine order of the moving parts of the
y,—in the circulation of living blood,—in the con-
al death of particles, and their removal from the
ne,—in the permanence of the individual whilst every
terial particle of his frame is a thousand times *
nged in the progress of his life. But this is alto-
her a distinct inquiry, and we are deterred from
ching upon it, not more from knowing that our readers
not initiated into it, than from the depth and very
t difficulty of the subject.

The old philosophers gave out that the human body was
n times changed during the natural life. Modern dis-
ries have shown that the hardest material of the frame
anging continually; that is, every instant of time, from
to death.

CHAPTER I.

ARCHITECTURE OF THE SKULL.

It requires no disquisition to prove that the brain is the most essential organ of the animal system, and being so, we may presume that it must be especially protected. We are now to inquire how this main object is attained?

We must first understand that the brain may be hurt, not only by sharp bodies touching and entering it, but by a blow upon the head, which shall vibrate through it, without the instrument piercing the skull. Indeed, a blow upon a man's head, by a body which shall cause a vibration through the substance of the brain, may more effectually deprive him of sense and motion than if an axe or a sword penetrated into the substance of the brain itself.

Supposing that a man's ingenuity were to be exercised in contriving a protection to the brain, he must perceive that if the case were soft, it would be too easily pierced; that if it were of a glassy nature, it would be chipped and cracked; that if it were of a substance like metal, it would ring and vibrate, and communicate the concussion to the brain.

Further thoughts might suggest, that whilst the case should be made firm to resist a sharp point, the vibrations of that circular case might be prevented by lining it with a softer material; no bell would vibrate with such an incumbrance; the sound would be stopped like the ringing of a glass by the touch of a finger.

If a soldier's head be covered with a steel cap, the blow of a sword which does not penetrate will yet bring him to the ground by the percussion which extends to the brain; therefore, the helmet is lined with leather, and covered with hair; for, although the hair is made an ornament, it is an essential part of the protection: we may see it in the head-piece of the Roman soldier, where all useless ornament, being despised as frivolous, was avoided as cumbrous.

We now perceive why the skull consists of two plates of bone, one external, which is fibrous and tough, and one internal, dense to such a degree that the anatomist calls it *tabula vitrea* (the glassy table).

Nobody can suppose this to be accidental. It has just been stated, that the brain may be injured in two ways: a stone or a hammer may break the skull, and the depressed part of the bone injure the brain; whilst, on the other hand, a mallet struck upon the head will, without penetrating, effectually deprive the brain of its functions, by causing a vibration which runs round the skull and extends to every portion of its contents.

Were the skull, in its perfect or mature state, softer than it is, it would be like the skull of a child; were it harder than we find it is, it would be like that of an old man. In other words, as in the former it would be too easily pierced, so, in the latter, it would vibrate too sharply and produce concussion. The skull of an infant is a single layer of elastic bone; on the approach to manhood it separates into two tables; and in old age it again becomes consolidated. During the active years of man's life the skull is perfect: it then consists of two layers united by a softer substance; the inner layer is brittle as glass, and calculated to resist anything penetrating; the outer table is tough, to give consistence, and to stifle the vibration which would take place if the whole texture were uniform and like the inner table.

The alteration in the substance of the bones, and more particularly in the skull, is marvellously ordered to follow the changes in the mind of the creature, from the heedlessness of childhood to the caution of age, and even the helplessness of superannuation.

The skull is soft and yielding at birth; d
hood it is elastic, and little liable to injury
sion; and during youth, and up to the perio

the parts which come in contact with t
thicker, whilst the shock is dispersed towa
(the seams or joinings of the pieces), v
loose. But when, with advancing years, s
us to give up feats of activity, and falls are
the bones lose that nature which would ren
harmless, and at length the timidity of ag
that his structure is no longer adapted to a

We must understand the necessity of th
of the skull, in order to comprehend anoth
contrivance. The sutures are the lines o
several bones which form the *cranium*,*
and protect the brain. These lines of un
sutures (from the Latin word for *sewing*),
resemble seams. If a workman were to in
ing of two of the bones of the cranium, he
the minute dove-tailing by which one p
bone is inserted into, and surrounded b
whilst that other pushes its processes o
between those of the first in the same ma
fibres of the two bones are thus interlaced
interlace your fingers. But when you look
surface, you see nothing of this kind; the l
laid simply in contact, and this line by
called *harmonia*, or harmony: architects
term to imply the joining by masonry
anatomists are thus curious in names, it is
find them negligent of things more interes
overlooked the reason of the difference in
bone, they are consequently blind to the
difference of the outward and inward part

Suppose a carpenter employed upon his
he would join a box with minute and regul
by dovetailing, because he knows that th

---

* *Cranium*, from a Greek word signify
The cranium is the division of the skull app
protection of the brain; it consists of six bon
(or forehead); two *parietal* (walls or sid
occipital (back of the head); and two *tempo*
bones.

ich he works, from its softness and toughness, admits such adjustment of its edges. The processes of the ie shoot into the opposite cavity with an exact resem- nce to the foxtail wedge of the carpenter—a kind of on and mortice when the pieces are small.

But if a workman in glass or marble were to inclose ne precious thing, he would smooth the surfaces and te them by cement, because, even if he could succeed indenting the line of union, he knows that his ma- ial would chip off on the slightest vibration. The ges of the marble cylinders which form a column are, the same reason, not permitted to come in contact; n plates of lead are interposed to prevent the edges, :hnically termed *arrises*, from chipping off or split- ig.

Now apply this principle to the skull. The outer fter tough table, which is like wood, is indented and ›vetailed; the inner glassy table has its edges simply id in contact. It is mortifying to see a course of bad asoning obscure this beautiful subject. They say that ie bone growing from its centre, and diverging, shoots fibres betwixt those which come in an opposite direc-)n; thus making one of the most curious provisions of ture a thing of accident. Is it not enough to ask such asoners why there is not a suture on the inside as well on the out?

The junction of the bones of the head generally being is exact, and like the most finished piece of cabinet rk, let us next inquire whether there be design or ntrivance shown in the manner in which each bone is iced upon another.

When we look upon the side of the skull (as in the ure at p. 29), the temporal suture betwixt the bones A d D is formed in a peculiar manner; the lower, or nporal, bone laps over the superior, or parietal, bone. iis, too, has been misunderstood: that is to say, the n of the building of the bones of the head has not en considered; and this joining, called the squamous* suture, which is a species of scarfing, has be posed a mere consequence of the pressure of th which moves the jaw.

---

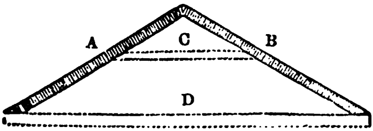
* From *squama*, the Latin for a *scale*, the thin edges lying r each *other like* the scales of a fish.

Dr. Monro says, "the manner how I imagine of suture is formed at these places, is, that by th of the strong temporal muscles on one side, an pressure of the brain on the other, the bones a so thin that they have not large enough surfaces to each other to stop the extension of their length, and thus to cause the common serrated ance of sutures; but the narrow edge of the o slides over the other."

The very name of the bones might suggest explanation. The *ossa parietalia* * are the tv bones in a regular square, serving as walls to the or room of the head, where the brain is lodged *in the foregoing figure.*

Did the reader ever notice how the walls of are assisted when thin and overburdened with a

The *wall plate* is a portion of timber built wall, to which a transverse or tie-beam is att carpentry. This *cogging*, as it is termed, keeps in the perpendicular, and prevents any lateral of the roof. We sometimes see a more clun trivance, a clasp, or a round plate of iron, upon of a wall; this has a screw going into the ends of beam, and by embracing a large portion of th work, it holds the wall from shifting at this po take the instance of a roof supported on incline A B:



Were they thus, without further security, plac the walls, the weight would tend to spur or pres alls, which must be strong and heavy to support the oof; therefore, the skeleton of the roof is made into a *uss* (for so the whole joined carpentry is called). The pper cross-beam marked by the dotted lines c, is a llar-beam, connecting the rafters of the roof, and iffening them, and making the weight bear perpendicu- rly upon the walls. When the transverse beam joins e extremities of the rafters, as indicated by the lower tline D, it is called a *tie-beam*, and is more powerful ill in preventing the rafters from pushing out the alls.

---

* From the Latin word *paries*, a wall.

Now when a man bears a burden upon his head, the essure, or horizontal push, comes upon the lower part the *parietal bones*, and if they had not a tie-beam, ey would, in fact, be spurred out, and the bones of the ad be crushed down. But the temporal bone D, and ill more, the sphenoid bone E, by running across the se of the skull, and having their edges lapping over e lower part of the great walls, or the parietal bones, ck in the walls as if they had iron plates, and answer e purpose of the tie-beam in the roof, or the iron plate the walls. But the connexion is at the same time so cure, that these bones act equally as a *straining* piece, at is, as a piece of timber, preventing the tendency of e sides *of the skull* to each other.

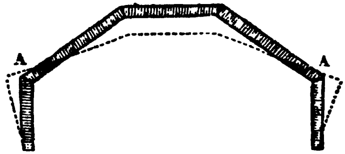
It may be said, that the skull is not so much like the all of a house as like the arch of a bridge: let us then nsider it in this light.

We have here the two parietal bones, separated and sting against each other, so as to form an arch. In e centering, which is the wooden frame for supporting stone arch while building, there are some principles at are applicable to the head.

We see that the arch formed by the two parietal bones ee fig. at p. 30) is not a perfect semicircle; there is a ojection at the centre of each bone, the bone is more nvex, and thicker at this part.

The cause assigned for this is, that it is the point from hich ossification begins, and where it is, therefore, most rfect. But this is to admit a dangerous principle, that the forms of the bones are matter of chance: thence we are left without a motive for study, and m no endeavour to comprehend the uses of parts. We f that all the parts which are most exposed to injury thus strengthened;—the centre of the forehead, the p jecting point of the skull behind, and the lateral cent of the parietal and frontal bones. The parts of the h which would strike upon the ground when a man f are the strongest, and the projecting arch of the pari bone is a protection to the weaker temporal bone.

If we compare the skull to the *centering*, where a bri is to be built over a navigable river, and conseque where the space must be free in the middle, we find t the scientific workmen are careful, by a transverse be to protect the points where the principal thrust will made in carrying up the masonry: this beam does not as a tie-beam, but as a straining-piece, preventing arch from being crushed in at this point.



The necessity of strengthening certain points is exhibited in the carpentry of roofs. In this figure clear, that the points A A will receive the pressure of roof, and if the joining of the puncheons* and rafter not secure, it will sink down in the form of the d line. The workmen would apply braces at these a to strengthen them.

In the arch, and at the corresponding points o rietal bones, the object is attained by strengthening ese points by increase of their convexity and thickness; d where the workman would support the angles by aces, there are ridges of bone, in the calvaria,* or roof the skull.

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* The puncheons are the upright lateral pieces; the r are the timbers which lie oblique, and join the puncl at A A.

If a stone arch fall, it must give way in two places at e same time; the centre cannot sink unless that part the arch which springs from the pier yields: and in arches, from the imperfect Roman arch to that built on modern principles, the aim of the architect is to give urity to this point.

In the Roman bridges still entire the arch rises high, th little inclination at the lower part; and in bridges a more modern date, we see a mass of masonry erected the pier, sometimes assuming the form of ornament, netimes of a tower or gateway, but obviously intended the same time, by the perpendicular load, to resist the izontal pressure of the arch. If this be omitted in re modern buildings, it is supplied by a finer art, ich gives security to the masonry of the pier (to row the terms of anatomy) by its internal structure.

In what is termed Gothic architecture, we see a flying tress, springing from the outer wall, carried over the f of the aisle, and abutting against the wall of the per part, or *clerestory*. From the upright part of s masonry a pinnacle is raised, which at first appears be a mere ornament, but which is necessary, by its pendicular weight, to counteract the horizontal thrust the arch.

By all this, we see that if the skull is to be considered an arch, and the parietal bones as forming that arch, y must be secured at the temporal and sphenoid†

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* From the Latin *calva* or *calvaria*, a *helmet*.

† In the Greek, *sphenoid*—in the Latin, *cuneiform*—like a dge, because it is wedged among the other bones of the d; but these processes, called wedges, are more like etails, which enter into the irregularities of the bones, hold them locked.

bones, the points from which they spring. An point of fact, where is it that the skull yields w man falls, so as to strike the top of his head upo ground ?—in the temples. And yet the joinings secure, that the extremity of the bone does not star its connexions. It must be fractured before it is s out, and in that case only does the upper part of th yield.

But the best illustration of the form of the head dome.

A dome is a vault rising from a circular or elli base; and the human skull is, in fact, an elliptica mounted dome, which latter term means that the is higher than the radius of its base. Taking this historically, we should presume that the dome wa difficult piece of architecture, since the first dome ed appears to have been at Rome, in the reign of ustus—the Pantheon, which is still entire. The of St. Sophia, in Constantinople, built in the time e Emperor Justinian, fell three times during its erec- : and the dome of the Cathedral of Florence stood ished one hundred and twenty years for want of an itect. Yet we may, in one sense, say that every ler who tried it, as well as every labourer employed, the most perfect model in his own head. It is ous enough, that the weight of the upper part of the must disengage the stones from each other which the lower circle, and tend to break up their join- , and consequently to press or thrust outwards the ilar wall on which it rests. No walls can support the ht, or rather, the lateral thrust, unless each stone e dome be soldered to another, or the whole hooped ther and girded: The dome of St. Paul's has a very g double iron chain, linked together, at the bottom he cone; and several other lesser chains between and the cupola, which may be seen in the section of Paul's engraved by Hooker.

he bones of the head are securely bound together, so the anatomist finds, when every thing is gone, save bone itself, and there is neither muscle, ligament, membrane of any kind, to connect the bones, they still, securely joined, and it requires his art to burst asunder; and for this purpose he must employ a which shall produce a uniform pressure from the re outwards; and all the sutures must receive the ure at one time and equally, or they will not give

And now is the time to observe another circum e, which calls for our admiration. So little of ent is there in the joining of the bones, that the of a bone at the suture lies over the adjoining bone e part and under it at another, which, with the tailing of the suture, as before described, holds each in its place firmly attached; and it is this which security to the dome of the cranium.

If we look at the skull in front, we may consider the orbits of the eye as crypts under the greater building. And these under-arches are groined, that is to say, there are strong arched spines of bone, which give strength sufficient to permit the interstices of the groinings, if I may so term them, to be very thin. Betwixt the eye and the brain, the bone is as thin as parchment; but if the anterior part of the skull had to rest on this, the foundation would be insufficient. This is the purpose of the strong ridge of bone which runs up like a buttress from the temple to the lateral part of the frontal bone, whilst the arch forming the upper part of the orbit is very strong: and these ridges of bone, when the skull is formed with what we call a due regard to security, give an extension to the forehead.*

In concluding this survey of the architecture of the head, let us suppose it so expanded that we could look upon it from within. In looking up to the vault, we should at once perceive the application of the *groin* in masonry; for the groin is that projection in the vault which results from the intersection of two arches running in different directions. One rib or groin extends from the centre of the frontal bone to the most projecting part of the occipital foramen, or opening on the back of the head; the other rib crosses it from side to side of the occipital bone. The point of intersection of these two groins is the thickest and strongest part of the skull, and it is the most exposed, since it is the part of the head which would strike upon the ground when a man falls backwards.

What is termed the base of the skull is strengthened, if we may so express it, on the same principle: it is like a cylinder groin, where the rib of an arch does not nınate upon a buttress or pilaster, but is continued nd in the completion of the circle. The base of the ll is irregular, and in many places thin and weak, but se arched spines or ribs give it strength to bear those ›cks to which it is of course liable at the joining of the ıll with the spine.

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* Although they are solid arches connected with the building of the cranium, and bear no relation to the surface of the brain, the early craniologists would have persuaded us that their forms correspond with the surfaces of the brain, and indicate particular capacities or talents.

CHAPTER II.

MECHANISM OF THE SPINE.

THE brain-case is thus a perfect whole, secure c sides, and strengthened where the exposure to inj the greatest. We shall see, in the column whic tains it, equal provision for the security of the b and, what is most admirable, there is an entirely dif principle introduced here; for whereas in the heac whole aim is firmness in the joinings of the bon the spine which supports the head, the object to l tained is mobility or pliancy. In the head, each b firmly secured to another; in the spine, the bon not permitted to touch: there is interposed a sol elastic material, which takes off the jar that would from the contact of the bones. We shall conside subject a little more in detail.

The spinal column, as it is called, serves three poses: it is the great bond of union betwixt all the of the skeleton; it forms a tube for the lodgment c spinal marrow, a part of the nervous system as imp to life as the brain itself; and lastly, it is a colu sustain the head.

We now see the importance of the spine, and we next explain how the various offices are provided fc

If the protection of the spinal marrow had bee only object of this structure, it is natural to infer t would have been a strong and unyielding tube of but, as it must yield to the inflexions of the body, i not be constituted in so strict an analogy with the It must, therefore, bend; but it must have no abru considerable bending at one part; for the spinal m *within* would in this way suffer.

this consideration we perceive why there are
y-four bones in the spine, each bending a little;
articulated or making a joint with its fellow; all
ding in a slight degree, and, consequently, permitting
he whole spine that flexibility necessary to the mo-
as of the body. It is next to be observed that, whilst
e spine by this provision moves in every direction, it
ins a property which it belongs more to our present
rpose to understand. The bones of the spine are called
ertebræ; at each interstice between these bones there
a peculiar gristly substance, which is squeezed out
om betwixt the bones, and, therefore, permits them to
proach and play a little in the motions of the body.
is gristly substance is inclosed in an elastic binding,
membrane of great strength, which passes from the
ge or border of one vertebra to the border of the one
xt it. When a weight is upon the body, the soft
stle is pressed out, and the membrane yields: the mo-
nt the weight is removed, the membranes recoil by
ir elasticity, the gristle is pressed into its place, and
bones resume their position.

We can readily understand how great the influence of
se twenty-four joinings must be in giving elasticity to
whole column; and how much this must tend to the
tection of the brain. Were it not for this interposi-
n of elastic material, every motion of the body would
duce a jar to the delicate texture of the brain, and we
uld suffer almost as much in alighting on our feet, as
falling on our head. It is, as we have already re-
rked, necessary to interpose thin plates of lead or slate
ween the different pieces of a column to prevent the
ges (technically called arrises) of the cylinders from
ning in contact, as they would, in that case, chip or
it off.

But there is another very curious provision for the pro-
tion of the brain: we mean the curved form of the
ne. If a steel spring, perfectly strai ed
wixt the hands from its extremities,
hstanding its elasticity, and when it
l be with a jerk. Such would be

spine if it stood upright, one bone perpendici
another; for then the weight would bear equall
spine would·yield neither to one side nor to the
and, consequently, there would be a resistance fr
pressure on all sides being balanced. We, therefo
the great advantage resulting from the human spine
in the form of an italic *f*. It is prepared to yield
direction of its curves; the pressure is of necessity
upon one side of the column than on the other;
elasticity is immediately in operation without a je
yields, recoils, and so forms the most perfect
admirably calculated to carry the head without jar
jury of any kind.

The most unhappy illustration of all this is th
dition of old age. The tables of the skull are the
solidated, and the spine is rigid: if an old man
fall with his head upon the carpet, the blow,
would be of no consequence to the elastic fran
child, may to him prove fatal; and the rigidity
spine makes every step which he takes vibrate to
terior of the head, and jar on the brain.

We have hinted at a comparison betwixt the
ment of the spine to the pelvis and the insertion
mast of a ship into the hull. The mast goes
through the decks without touching them, and tl
of the mast goes into the step, which is formed o
solid pieces of oak timber laid across the keelson
keelson is an inner keel resting upon the floor-tim
the ship and directly over the proper keel. Th
contrivances for enlarging the base on which tl
rests as a column: for as, in proportion to the hei
weight of a column, its base must be enlarged
would sink into the earth; so, if the mast were
upon a point, it would break through the bottom
ship.

The mast is supported upright by the shro
stays. The shrouds secure it against the lateral
ing motion, and the stays and backstays against the
ing of the ship. These form what is termed the
ing rigging. The mast does not bear upon the d

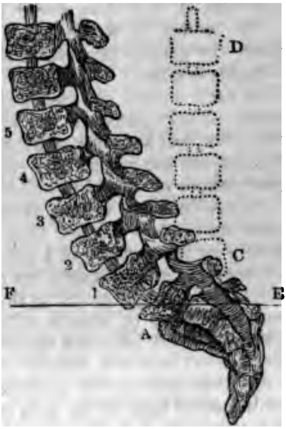
on the beams of the ship; indeed there is a space covered with canvas betwixt the deck and the mast.

We often hear of a new ship going to sea to stretch her rigging; that is, to permit the shrouds and stays to be stretched by the motion of the ship, after which they are again braced tight: for if she were overtaken by a storm before this operation, and when the stays and shrouds were relaxed, the mast would lean against the upper deck, by which it would be sprung or carried away. Indeed, the greater proportion of masts that are lost are lost in this manner. There are no boats which keep the sea in such storms as those which navigate the gulf of Finland. Their masts are not attached at all to the hull of the ship, but simply rest upon the step.

Although the spine has not a strict resemblance to the mast, the contrivances of the ship-builder, however different from the provisions of nature, show what object is to be attained; and when we are thus made aware of what is necessary to the security of a column on a moveable base, we are prepared to appreciate the superior provisions of nature for giving security to the human spine.

The human spine rests on what is called the *pelvis*, or basin;—a circle of bones, of which the haunches are the extreme lateral parts; and the sacrum (which is as the keystone of the arch) may be felt at the lower part of the back. To this central bone of the arch of the pelvis the spine is connected; and, taking the similitude of the mast, the sacrum is as the *step* on which the base of the pillar, like the heel of the mast, is socketed or mortised. The spine is tied to the lateral parts of the pelvis by powerful ligaments, which may be compared to the shrouds. They secure the lower part of the spine against the shock of lateral motion or rolling; but, instead of the stays to limit the play of the spine forwards and backwards in pitching, or to adjust the rake of the mast, there is a very beautiful contrivance in the lower part of the column.

The spine forms here a semicircle his effect; that, whether by the exertion tremities, *the spine* is to be carried pelvis, or whether the body stops suddenly in running, the jar which would necessarily take place at the lower part of the spine A, if it stood upright like a mast, is distributed over several of the bones of the spine, 1, 2, 3, 4, and, therefore, the chance of injury at any particular part is diminished.



For example, the sacrum, or centre bone of the pelvis, being carried forward, as when one is about to run, the force is communicated to the lowest bone of the spine. But, then, the surfaces of these bones stand with a very slight degree of obliquity to the line of motion; the shock communicated from the lower to the second bone of the vertebræ is still in a direction very nearly perpendicular to its surface of contact. The same takes place in the communication of force from the second to the third, and from the third to the fourth; so that before the shock of the horizontal motion acts upon the perpendicular spine, it is distributed over four bones of the

instead of the whole force being concentrated
e joining of any two, as at A.

e column stood upright, as indicated at C D, it
e jarred at the lowest point of contact with its
ut by forming a semicircle A B, the motion which
lirection E F would produce a jar on the very
art of the column, is distributed over a consider-
tion of the column A B; and in point of fact,
t of the spine never gives way. Indeed, we
e inclined to offer this mode to the consideration
al men, as fruitful in hints for improving naval
ure.

one who has seen a ship pitching in a heavy sea,
ve asked himself why the masts are not upright,
r, why the foremast stands upright, whilst the
d mizen masts stand oblique to the deck, or, as
se is, rake aft or towards the stern of the ship.
nain and mizen masts incline backwards, because
n is greatest in the forward pitch of the vessel;
nast having received an impulse forwards, it is
checked as the head of the ship rises; but the
ng set with an inclination backwards, the motion
re in the perpendicular line from the head to the
This advantage is lost in the upright position of
nast, but it is sacrificed to a superior advantage
n working the ship; the sails upon this mast act
werfully in swaying the vessel round, and the
icular position causes the ship to tack or stay
but the perpendicular position, as we have seen,
e strain in pitching to come at right angles to
, and is, therefore, more apt to spring it.

considerations give an interest to the fact, that
an spine, from its utmost convexity near its base,
backwards.

CHAPTER III.

OF THE CHEST.

In extending the parallel which we proposed b
the structure of the body and the works of huma
signifies very little to what part we turn; for the
adaptation of means to the end will everywhere ch
our admiration, in exact proportion to our success i
prehending the provisions which Supreme Wisd
made. We turn now to a short view of the bones
chest.

The thorax, or chest, is composed of bones an
tilages, so disposed as to sustain and protect the mo
parts, the heart and lungs, and to turn and twist wi
fect facility in every motion of the body; and to
incessant motion in the act of respiration, without
ment's interval during a whole life. In anatomi
scription, the thorax is formed of the vertebral c
or spine, on the back part, the ribs on either si
the breastbone, or sternum, on the fore part. B
thing most to be admired is the manner in whic
bones are united, and especially the manner in
the ribs are joined to the breastbone, by the inter
of cartilages, or gristle, of a substance softer than
and more elastic and yielding. By this quality t
fitted for protecting the chest against the effects
lence, and even for sustaining life after the m
power of respiration has become too feeble to c
without this support.

If the ribs were complete circles, formed of bo
extending from the spine to the breastbone, life
be endangered by any accidental fracture; and e
rubs and jolts to which the human frame is con

posed, would be too much for their delicate and brittle ture. But these evils are avoided by the interposition the elastic cartilage. On their forepart the ribs are ed out, and joined to the breastbone by means of carages, of a form corresponding to that of the ribs, being, it were, a completion of the arch of the rib, by a subnce more adapted to yield in every shock or motion of e body. The elasticity of this portion subdues those ocks which would occasion the breaking of the ribs. e lean forward, or to one side, and the ribs accommote themselves, not by a change of form in the bones, t by the bending or elasticity of the cartilages. A severe w upon the ribs does not break them, because their tremities recoil and yield to the violence. It is only youth, however, when the human frame is in perfecn, that this pliancy and elasticity have full effect. hen old age approaches, the cartilages of the ribs bene bony. They attach themselves firmly to the breastne, and the extremities of the ribs are fixed, as if the ole arch were formed of bone unyielding and inelastic. en every violent blow upon the side is attended with cture of the rib, an accident seldom occurring in childd, or in youth.

But there is a purpose still more important to be accomshed by means of the elastic structure of the ribs, as tly formed of cartilage. This is in the action of athing, or respiration; especially in the more highlysed respiration which is necessary in great exertions of ily strength, and in violent exercise. There are two s of breathing—*expiration*, or the sending forth of the ath; and *inspiration*, or the drawing in of the breath. hen the chest is at rest, it is neither in the state of exation nor in that of inspiration; it is in an intermediate dition between these two acts. And the muscular rt by which either inspiration or expiration is proed is an act in opposition to the elastic property of ribs. The property of the ribs is to preserve the ast in the intermediate state between expiration and piration. The muscles of respiration are excited alnately, to dilate or to contract the cavity of the chest, and, in doing so, to raise or to depress the ribs. Hence it is, that both in inspiration and in expiration the elasticity of the ribs is called into play; and, were it within our province, it would be easy to show, that the dead power of the cartilages of the ribs preserves life by respiration, after the vital muscular power would, without such assistance, be too weak to continue life.

It will at once be understood, from what has now been explained, how, in age, violent exercise or exertion is under restraint, in so far as it depends on respiration. The elasticity of the cartilages is gone, the circle of the ribs is now unyielding, and will not allow that high breathing, that sudden and great dilating and contracting of the cavity of the chest, which is required for circulating the blood through the lungs, and relieving the heart amidst the more tumultuous flowing of the blood which exercise and exertion produce.

CHAPTER IV.

DESIGN SHOWN IN THE STRUCTURE OF THE BONES AND JOINTS OF THE EXTREMITIES.

THAT the bones, which form the interior of animal bodies, should have the most perfect shape, combining strength and lightness, ought not to surprise us, when we find this in the lowest vegetable production.

In the sixteenth century, an unfortunate man who taught medicine, philosophy, and theology, was accused of atheistical opinions, and condemned to have his tongue cut out, and to suffer death. When brought from his cell before the Inquisition, he was asked if he believed in God. Picking up a straw which had stuck to his garments, "If," said he, "there was nothing else in nature to teach me the existence of a Deity, even this straw would be sufficient!"*

[A reed, or a quill, or a bone, may be taken to prove that in Nature's works strength is given with the least possible expense of materials. The long bones of animals are, for the most part, hollow cylinders, filled up with the lightest substance, marrow; and in birds the object is attained by means (if we may be permitted to say so) still more artificial. Every one must have observed, that the breast-bone of a fowl extends along the whole body, and that the body is very large compared with the weight: this is for the purpose of rendering the creature specifically lighter and more buoyant in the air; and that it may have a surface for the attachment of muscles, equal to the exertion of raising it on the wing. This combina-

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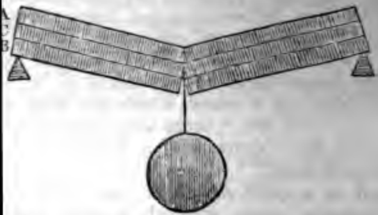
* The passage following, marked in brackets, on to p. 189, appears also in Sir C. Bell's Illustrations of Paley, p. 18. It could not be removed from its present place without disturbing the *coherence of the* argument.

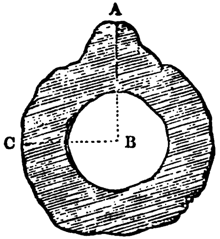
ghtness with increase of volume is gained by
xtending through the body, and communicating
between the lungs and cavities of the bones.
means, the bones, although large and strong to
the operation of powerful muscles upon them,
lighter than those of quadrupeds.
ng bones of the human body, being hollow tubes,
cylindrical, though they are not accurately so,
of which we shall presently explain; and we
he same time, show that their irregularities are
ntal, as some have imagined. But let us first
te the advantage which, in the structure of the
derived from the cylindrical form, or a form ap-
to that of the cylinder. If a piece of timber
on two points, thus—



ight upon it, it sustains this weight by different
in its different parts. For example, divide it
e equal parts (A, B, C): the upper part A sup-
weight by its solidity and resistance to compres-
lowest part B, on the other hand, resists by its
, or adhesive quality. Betwixt the portions
so different a manner there is an intermediate
r central part C, that may be taken away with-
ially weakening the beam, which shows that a
ylinder is the form of strength. The Writer
erved a good demonstration of this:—a large
blown down, and lay upon the ground; to the
, the broken part gaped; it had been torn
snapping of a rope: to the leeward side
res of the stem were crushed into one

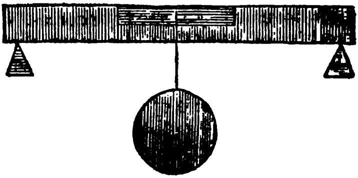
another and splintered; whilst the central part remained entire. This, we presume, must be always the case, more or less; and here we take the opportunity of noticing why the arch is the form of strength. If this transverse piece of timber were in the form of an arch, and supported at the extremities, then its whole thickness, its centre, as well as the upper and lower parts, would support weight by resisting compression. But the demonstration may be carried much farther to show the form of strength in the bone. If the part of the cylinder which bears the pressure be made more dense, the power of resistance will be much increased; whereas, if a ligamentous covering be added on the other side, it will strengthen the part which resists extension: and we observe a provision of this kind in the tough ligaments which run along the vertebræ of the back.

When we see the bone cut across, we are forced to acknowledge that it is formed on the principle of the cylinder; that is, that the material is removed from the centre, and accumulated on the circumference, thus—



We find a spine, or ridge running along the bone, which, when divided by the saw in a transverse direction, exhibits an irregularity, as at A.

The section of this spine shows a surface as dense as ivory, which is, therefore, much more capable of resisting compression than the other part of the cylinder, which is common bone. This declares what the spine is, and the anatomists must be wrong who imagine that *the bone is moulded* by the action of the muscle, and that the spine is a mere ridge, arising by accident among the muscles. It is, on the contrary, a strengthening of the bone in the direction on which the weight bears. If we resume the experiment with the piece of timber, we shall learn why the spine is harder than the rest of the bone. If a portion of the upper part of the timber be cut away, and a harder wood inserted in its place, the beam will acquire a new power of resisting fracture, because, as we have stated, this part of the wood does not yield but by being crushed, and the insertion of the harder portion of wood increases this property of resistance. With this fact before us we may return to the examination of the spine of bone. We see that it is calculated to resist pressure, first, because it is farther removed from the centre of the cylinder; and, secondly, because it is denser, to resist compression, than the other part of the circumference of the bone.*



This explanation of the use of a spine upon a bone gives a new interest to osteology.† The anatomist ought to deduce from the form of the spine the motions of the limb; the forces bearing upon the bone, and the nature and the common place of fracture; while to the general inquirer an agreeable process of reasoning is introduced in that department, which is altogether without interest when the "*irregularities*" of the bone are spoken of, as

* As the line A B extends farther from the centre than B C, on the principle of a lever, the resistance to transverse fracture will be greater in the direction A B than B C.

† *Osteology*, from the Greek words, signifying discourse on bone, being the demonstration of the forms and connexion of the different bones.

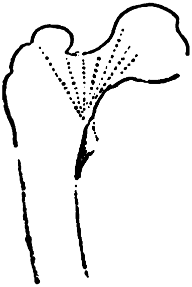
ere the accidental consequences of the pressure
h upon it.

gh treating of the purely mechanical principle,
aps, not far removed from our proper object to
hat a person of feeble texture and indolent
s the bone smooth, thin, and light; but that
licitous for our safety, in a manner which we
anticipate, combines with the powerful mus-
e a dense and perfect texture of bone, where
ne and tubercle is completely developed. And
inert and mechanical provisions of the bone
ear relation to the muscular power of the limb,
ise is as necessary to the perfect constitution of
it is to the perfection of the muscular power.
peak correctly enough, when they use the term
d bone," as distinguishing the breed or gene-
orses; for blood is an allowable term for the
bone is so far significant, that the bone of a
orse is remarkably compact compared with the
draught horse. The reader can easily under-
t the span in the gallop must give a shock in
to its length; and as in man, so in the horse,
er the muscular power the denser and stronger
e.

ne not being as a mere pillar, intended to bear
licular weight, we ought not to expect uni-
its shape. Each bone, according to its place,
gainst the varying forces that are applied to it.
two men wrestling together, and then think
us the property of resistances must be: here
ulling, and the bones are like ropes; or again,
rithing and twisting, and the bones bear a
the axle-tree between two wheels; or they
pillar under a great weight; or they are acting
]

stand these different shocks, a bone consists
arts, the *earth* of bone (sub-phosphate of lime);
ve it toughness; and *cartilage* to give it elas-
hese ingredients are not uniformly mixed up
es; but some bones are hard, from the preva-
e earth of bone; some more fibrous, to resist

a pull upon them; and some more elastic, to shocks in walking, leaping, &c. But to retur forms:—Whilst the centre of the long bones have stated, cylindrical, their extremities are e and assume various shapes. The expansion of of the bone is to give a greater, and consequentl secure surface for the joint, and its form regul direction in which the joint is to move. A jock ting his hand on the knee of a colt, and finding and flat, augurs the perfection of the full-grow To admit of this enlargement and difference of change in the internal structure of the bone is ne and the hollow of the tube is filled up with *ca* lattice-work. These *cancelli* of the bone are mi delicate, like wires, which form lattice-work, e in all directions through the interior of the bo which, were it elastic, would be like a sponge. more uniform texture of the bone permits the out to be very thin, so that whilst the centre of th bones are cylinders, their extremities are of a cancellated structure. But it is pertinent to our to notice, that this minute lattice-work, or the which constitute the interior structure of bone still reference to the forces acting on the bone;



The head of the thigh-bone, to show the direction of the c converging to the line of gravity.

oubts this, let him make a section of the upper and end of the thigh-bone, and let him inquire what : meaning of the difference in the *lie* of these mi- bony fibres, in the two extremities? He will find the head of the thigh-bone stands obliquely off from haft, and that the whole weight bears on what is ed the *inner trochanter:* and to that point, as to a 'ess, all these delicate fibres converge, or point from head and neck of the bone, which may be rudely esented in this way. (See fig., p. 190.)

'e may here notice an opinion that has been enter- :d, in regard to the size of animals. It is believed the material of bone is not capable of supporting ature larger than the ·elephant, or the *mastodon*, h is the name of an extinct animal of great size, the us remains of which are still found. This opinion intenanced by observing that their bones are very ;y, that their spines are of great thickness, and that hollow cylinders are almost filled up with bone. may be illustrated in this manner;—A soft stone cting from a wall may make a stile, strong enough ar a person's weight; but if it were necessary to e its length, the thickness must be more than dou- or a freestone substituted; and were it necessary to this freestone project twice as far from the wall, if doubled in thickness, it would not be strong ;h to bear a proportioned increase of weight: gra- nust be placed in its stead; and even the granite l not be capable of sustaining four times the weight ı the soft stone bore in the first instance. In the way the stones which form an arch of a large span be of the hardest granite, or their own weight l crush them. The same principle is applicable to ›nes of animals. The material of bone is too soft to an indefinite increase of weight; and it is another ation of what was before stated, that there is a rela- :stablished through all nature, and that the very ls which move upon the surface of the earth are rtioned *to its magnitude*, and the gravitation to its ›. Archdeacon Paley has with great propriety taken *stance of the form of* the ends of bones, as proving design in the mechanism of a joint. But there is something so highly interesting in the conformation of the whole skeleton of an animal, and the adaptation of any one part to all the other parts, that we must not let our readers remain ignorant of the facts, or of the important conclusions drawn from them.

What we have to state has been the result of the studies of many naturalists; but although they have laboured, as it were, in their own department of comparative anatomy, they have failed to seize upon it with the privilege of genius, and to handle it in the masterly manner of Cuvier.

Suppose a man ignorant of anatomy to pick up a bone in an unexplored country, he learns nothing, except that some animal has lived and died there; but the anatomist can, by that single bone, estimate, not merely the size of the animal, as well as if he saw the print of its foot, but the form and joints of the skeleton, the structure of its jaws and teeth, the nature of its food, and its internal economy. This, to one ignorant of the subject, must appear wonderful, but it is after this manner that the anatomist proceeds: let us suppose that he has taken up that portion of bone in the limb of the quadruped which corresponds to the human wrist; and that he finds that the form of the bone does not admit of free motion in various directions, like the paw of the carnivorous creature. It is obvious, by the structure of the part, that the limb must have been merely for supporting the animal, and for progression, and not for seizing prey. This leads him to the fact that there were no bones resembling those of the hand and fingers, or those of the claws of the tiger; for the motions which that conformation of bones permits in the paw would be useless without the rotation of the wrist—he concludes that these bones were formed in one mass, like the cannon-bone, pastern-bone, and coffin-bones of the horse's foot.*

---

* For these are solid bones, where it is difficult to recognise any resemblance to the carpus, metacarpus, and bones of the fingers; and yet comparative anatomy proves that these moveable bones are of the same class with those in the solid hoof of the *belluæ* of Linnæus.

; motion limited to flexion and extension of the foot oofed animal implies the absence of a collar-bone, restrained motion in the shoulder joint; and thus ıturalist, from the specimen in his hand, has got a :t notion of all the bones of the anterior extremity! notions of the extremities imply a condition of the which unites them. Each bone of the spine will that form which permits the bounding of the stag, : galloping of the horse, but it will not have that of joining which admits the turning or writhing of ›ine, as in the leopard or the tiger.

d now he comes to the head:—the teeth of a carnis animal, he says, would be useless to rend prey, ; there were claws to hold it, and a mobility of the nities like the hand, to grasp it. He considers, fore, that the teeth must have been for bruising , and the back teeth for grinding. The socketing se teeth in the jaw gives a peculiar form to these , and the muscles which move them are also pecuin short, he forms a conception of the shape of the

From this point he may set out anew, for by the ›f the teeth he ascertains the nature of the stomach, ength of the intestines, and all the peculiarities ι mark a vegetable feeder.

us the whole parts of the animal system are so con1 with one another, that from one single bone or ent of bone, be it of the jaw, or of the spine, or of :tremity, a really accurate conception of the shape, ıs, and habits of the animal, may be formed.

vill readily be understood that the same process of ıing will ascertain, from a small portion of a skelene existence of a carnivorous animal, or of a fowl, ι bat, or of a lizard, or of a fish; and what a con1 is here brought home to us, of the extent of that vhich adapts the members of every creature to its : office, and yet exhibits a system extending through ıole range of animated beings, whose motions are :ted by the operation of muscles and bones.

er all, this is but a part of the wonders disclosed ;h the knowledge of a thing so despised as a fragment of bone. It carries us into another science; since the knowledge of the skeleton not only teaches us the classification of creatures now alive, but affords proofs of the former existence of animated beings which are not now to be found on the surface of the earth. We are thus led to an unexpected conclusion from such premises: not merely the existence of an individual animal, or race of animals; but even the changes which the globe itself has undergone in times before all existing records, and before the creation of human beings to inhabit the earth, are opened to our contemplation.

Of Standing.

This may appear to some a very simple inquiry, and yet it is very ignorant to suppose that it is so. The subject has been introduced in this fashion:—"Observe these men engaged in raising a statue to its pedestal with the contrivances of pulleys and levers, and how they have placed it on the pedestal and are soldering it to keep it steady, lest the wind should blow it down. This statue has the fair and perfect proportions of the human body; to all outward appearance it ought to stand."

In the following passage we have the same idea thrown out in a manner which we are apt to call *French*. Were a man cast on a desert shore, and there to find a beautiful statue of marble, he would naturally exclaim,—"Without doubt, there have been inhabitants here: I recognise the hand of a famous sculptor: I admire the delicacy with which he has proportioned all the members of the body to give them beauty, grace, and majesty, to indicate the motion and expression of life." But it may be asked, what would such a man think if his companion were to say,—"Not at all—no sculptor made this statue; it is formed, to be sure, in the best taste, and according to the rules of art, but it is formed by chance: among the many fragments of marble, there has been one that formed of itself. The rain and the winds have detached it from the mountain, and a storm has placed it upright on the pedestal. The pedestal, too, was prepared of itself in this lonely place. True, it is like the Apollo, or

Venus, or the Hercules. You might believe that
igure lived and thought; that it was prepared to
e and speak; but it owes nothing to art; blind
ce has placed it there." *

he first passage suggests the conviction that the
er of standing proceeds not from any symmetry, as
pillar, or from gravitation alone. It, in fact, pro-
s from an internal provision, by which a man is
ble of estimating, with great precision, the inclina-
of his body, and correcting the bias by the adjust-
t of the muscles. In the second passage, it is meant
e shown that the outward proportion of the form
s a relation to the internal structure; that grace and
ession are not superficial qualities, and that only the
ne Architect could form such a combination of ani-
d machinery.

e shall consider how the human body is prepared by
anical contrivances to stand upright, and by what
sense of the gravitation of the body the muscles are
ted to stiffen the otherwise loose joints, and to poise
body on its base.

Of the Foot.

et us take the arrangement of the bones of the foot,
rding to the demonstration of the anatomists.

hey are divided into the *tarsus*, which is composed
ven bones, reaching from the heel to the middle of
foot. The *metatarsus*, which consists of five long
s laid parallel to each other, and extending from the
s to the roots of the toes. The bones of the toes are
d *phalanges*, from being in the form of a *phalanx*.

here are in all thirty-six bones in the foot; and the
question that naturally arises, is, why should there
o many bones? The answer is, In order that there
be so many joints; for the structure of a joint not
permits motion, but bestows elasticity.

joint then consists of the union of two bones, of
a form as to permit the necessary motion: but they

Démonstration de l'Existence de Dieu, par Fénélon.

are not in contact: each articulating surface
with cartilage, to prevent the jar which w
from the contact of the bones. This cartilag
and the celebrated Dr. Hunter discovered th
ticity was in consequence of a number of filam
compacted, and extending from the surface o
so that each filament is perpendicular to th
made upon it. The surface of the articulatin
is perfectly smooth, and is lubricated by a
synovia, signifying a mucilage, a viscous or t
This is vulgarly called *joint-oil*, but it has n
of oil, although it is better calculated than
lubricate the interior of the joint.

When inflammation comes upon a joint,
not supplied, and the joint is stiff, and the su
upon one another like a hinge without oil.
membrane extends from bone to bone, co
lubricating fluid, and forming the boundary
termed the cavity of the joint, although, in f
no unoccupied space. External to this cap
joint there are strong ligaments going from p
of the bones, and so ordered as to bind th
without preventing their proper motions.
description of a single joint, we can easily co
a spring or elasticity is given to the foot, wh
six bones are jointed together.

An elegant author has this very natural re
joints:—"In considering the joints, there
perhaps, which ought to move our gratitude
the reflection, *how well they wear*. A limb
upon its hinge, or play in its socket, many hu
in an hour, for sixty years together, without
of its agility, which is a long time for anyth
for anything so much worked and exercised
are. This durability I should attribute, in
provision which is made for the preventing
tear: first, by the polish of cartilaginous su
condly, by the healing lubrication of the muc

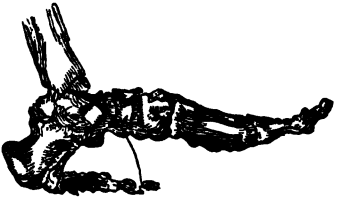
* From capsula, a little case, or box

o that astonishing property of animal constitu-
imilation, by which, in every portion of the
it consist of what it will, substance is restored
repaired."—*Paley*.

ingenious author's mind had been professionally
contemplate this subject, he would have found
xplanation. There is no resemblance betwixt
isions against the wear and tear of machinery
for the preservation of a living part. As the
of the parts is originally perfected by the
the vessels, the function or operation of the
ade the stimulus to those vessels. The cuticle
nds wears away like a glove; but the pressure
the living surface to force successive layers of
er that which is wearing, or, as the anatomists
lesquamating; by which they mean, that the
oes not change at once, but comes off in
or scales. The teeth are subject to pressure
ng or masticating, and they would, by this
ave been driven deeper in the jaw, and ren-
eless, had there not been a provision against
hanical effect. This provision is a disposition
or rather to shoot out of their sockets; and
sition to project, balances the pressure which
ain; and when one tooth is lost, its opposite
l is in danger of being lost also, for want of
opposition.

ost obvious proof of contrivance is the junction
ot to the bones of the leg at the ankle joint.
bones of the leg, called the *tibia* and the *fibula*,
e great articulating bone of the foot (the *astra-*
etwixt them. And the extremities of these
the leg project so as to form the outer and
kle. Now, when we step forward, and whilst
is raised, it rolls easily upon the ends of these
that the toe may be directed according to the
ies of the ground we are to tread upon; but
foot is planted, and the body is carried forward
cularly over the foot, the joint of the leg and
mes fixed, and we have a steady base to rest

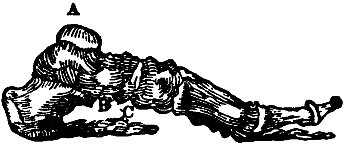
upon. We next observe, that, in walking, the heel first touches the ground. If the bones of the leg were perpendicular over the part which first touches the ground, we should come down with a sudden jolt, instead of which we descend in a semicircle, the centre of which is the point of the heel.



And when the toes have come to the ground we are far from losing the advantages of the structure of the foot, since we stand upon an elastic arch, the hinder extremity of which is the heel, and the anterior the ball of the toes. A finely formed foot should be high in the instep. The walk of opera dancers is neither natural nor beautiful; but the surprising exercises which they perform give to the joints of the foot a freedom of motion almost like that of the hand. We have seen the dancers, in their morning exercises, stand for twenty minutes on the extremities of their toes, after which the effort is to bend the inner ankle down to the floor, in preparation for the Bolero step. By such unnatural postures and exercises the foot is made unfit for walking, as may be observed in any of the retired dancers and old *figurantes*. By standing so much upon the toes, the human foot is converted to something more resembling that of a quadruped, where the heel never reaches the ground, and where the paw is nothing more than the phalanges of the toes.

This arch of the foot, from the heel to the toe, has the astragalus (A) resembling the keystone of an arch; *but*, instead of being fixed, as in masonry, it plays freely

wixt two bones, and from these two bones, B and C,
rong elastic ligament is extended, on which the bone
rests, sinking or rising as the weight of the body
rs upon it, or is taken off, and this it is enabled to do
the action of the ligament which runs under it.

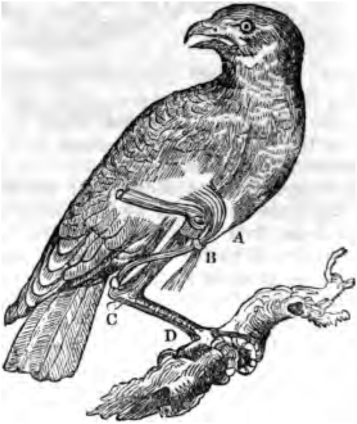


'his is the same elastic ligament which runs exten-
ly along the back of the horse's hind leg and foot,
gives the fine spring to it, but which is sometimes
ured by the exertion of the animal in a leap, pro-
ng irrecoverable lameness.

[aving understood that the arch of the foot is per-
from the heel to the toe, we have next to observe,
there is an arch from side to side; for when a
sverse section is made of the bones of the foot, the
osed surface presents a perfect arch of wedges, re-
irly formed like the stones of an arch in masonry.
'e look down upon the bones of the foot, we shall see
: they form a complete circle horizontally, leaving a
e in their centre. These bones thus form three dif-
nt arches—forward, across, and horizontally: they
wedged together, and bound by ligaments, and this
hat we alluded to when we said that the foundations
the Eddystone were not laid on a better principle;
our admiration is more excited in observing, that the
es of the foot are not only wedged together, like the
rses of stone for resistance, but that solidity is com-
ed with elasticity and lightness.

Notwithstanding the mobility of the foot in some po-
ns, yet when the weight of the body bears directly
it, it becomes immoveable, and the bones of the leg
t be fractured before the foot yields.

Ve shall proceed to explain how the knee-joint and hip-joint, independently of the exertion of muscle come firm in the standing position, and when at but, before we enter upon this, let us understan much talked-of demonstration of Borelli, who expl the manner in which a bird sits upon a branch asleep—the weight of the creature, and the conse flexion of the limbs, drawing the tendons of the t so as to make them grasp the branch without mu effort.



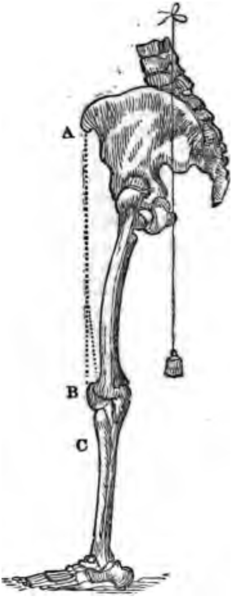
The muscle A passing over the joint at B, and thei ceeding to the back of the leg, and behind the j c, and so descending behind the foot at D, it exte the talons; and the weight of the bird, bending th B and C, produces the effect of muscular effort, and the claws cling.

But why should the anatomist have recourse t piece of comparative anatomy, when he has so f example in the human body? And one which is more interesting, as, in fact, it is the foundati

oning upon the diseases and accidents of the limb.
his beautiful arrangement in the healthy and perfect
cture of a man's limb be not attended to, it would be
to prove that many important circumstances, in re-
l to disease and accidents, must remain obscure.

'he posture of a soldier under arms, when his heels
close together, and his knees straight, is a condition
ainful restraint. Observe, then, the change in the
y and limbs, when he is ordered to stand at ease;
firelock falls against his relaxed arms, the right knee
rown out, and the tension of the ankle joint of the
e leg is relieved, whilst he loses an inch and a half
is height, and sinks down upon his left hip. This
mand to "stand at ease" has a higher authority than
general orders. It is a natural relaxation of all the
cles; which are, consequently, relieved from a pain-
state of exertion: and the weight of the body bears
pon the lower extremity, as to support the joints
ependently of muscular effort. The advantage of
will be understood, when we consider that all mus-
ar effort is made at the expense of a living power,
ch, if excessive, will exhaust and weary a man, whilst
position of rest which we are describing is without
rt, and therefore gives perfect relief. And it is this
ich makes boys and girls, who are out of health and
guid, lounge too much in the position of relief, from
ence comes permanent distortion.

The following figure represents the bones of the leg.
The plumb-line shows the direction of the gravitation
the body falling behind the head of the thighbone.
w, if it be understood that the motions of the trunk
performed on the centre of the head of the thigh-
e, it must follow that the weight of the body in the
ection of the plumb-line must raise the corner of the
nch-bone, at A. From this corner of the bone, a
ad and strong band runs down to the knee-pan, B, in
direction of the dotted line. The powerful muscles
ich extend the leg are attached to the knee-pan, and
ough the ligament at C, operate on the bones of the
stretching them, and preventing the flexion of the



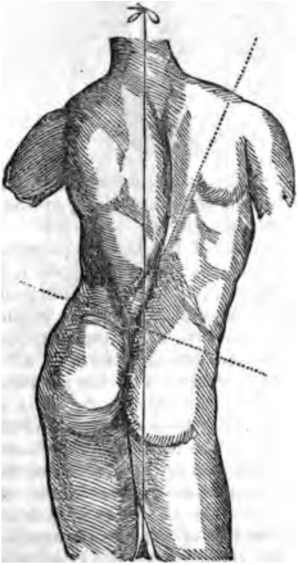
joint; but, in the absence of the activity of muscles, the band reaching from A to B, drawn, have said, by the weight of the body, is equivale the exertion of the muscles, braces the knee-joint extends the leg; and we have before seen that th tension of the leg fixes the ankle-joint. Thus the is made a firm pillar under the weight of the body, out muscular effort.

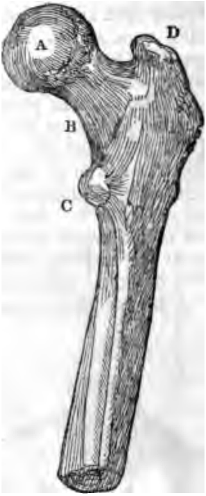
When the human figure is left to its natural atti we see a variety and contrast in the position of the and limbs.

This position of the body resting on the lower ties throws the trunk into an elegant line, and places e limbs in beautiful contrast, as we see in all the best ecimens of sculpture. (See below.)

Now that we have understood that the lower extremity comes in some positions a firm pillar, it is the more cessary to observe the particular form of the head of e thigh-bone. (See next page.)

It is here seen that the head of the bone A stands off m the shaft by the whole length of the neck of the ne B; the effect of this is, that as the powerful scles are attached to the knobs of bone C D, they turn e thigh-bone round in walking with much greater wer than if the head of the bone were on a line with e shaft. They, in fact, acquire a lever power, by the

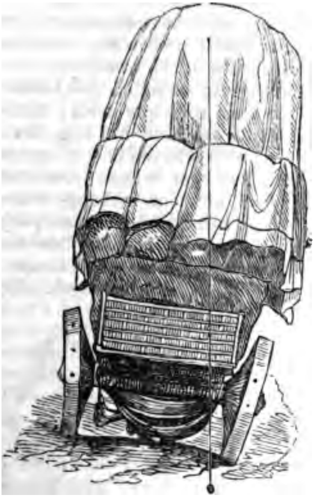




distance of D from A; as, during the action of these muscles, the limb is stiff, the rolling of the thigh directs the toe outwards in walking.

When the weight of the body is perpendicularly over the ball of the great toe, the whole body is twisted round on that point as on a pivot. This rolling of the body on the ball of the toe, and consequent turning out of the toes in stepping forward, is necessary to the freedom and elasticity of the motion. The form of all the bones of the leg, and the direction of all the muscles of the thigh and leg, combine to this effect. So far is it from being true, as painters affect to say, that the turning out of the toes is the result of the lessons of the dancing-master.

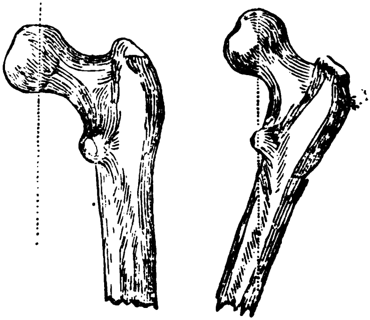
A certain squareness in the position of the feet is consistent with strength, as we see in the statues of the Hercules, &c.; but the lightness of a Mercury is indicated by the direction of the toes outwards. In women, there would be a defect from the breadth of the pelvis and a rolling and an awkward gait would be the consequence; but in them the foot is more turned out, and a light, elastic step balances the defect arising from the form of the pelvis. Any one may be convinced of this by observing people who walk awkwardly, especially if they walk unequally. Look at their feet, and you will see that one foot goes straight forward, whilst the other is turned outwards, and that when they come upon the straight foot, they come down awkwardly, and have no spring from it.



There is another curious circumstance in the form of the thigh-bone, showing how it is calculated for strength as well as freedom of motion. To understand it, we must first look to the *dishing* of a wheel—the dishing is the oblique position of the spokes from the nave to the felly, giving the wheel a slightly conical form. When a cart is *in the middle* of a road, the load bears equally upon both wheels, and both wheels stand with their spokes oblique to the line of gravitation.

If the cart is moving on the side of a barrel-shaped road, or if one wheel falls into a rut, the whole weight comes upon one wheel: but the spokes of that wheel, which were oblique to the load when it supported only one-half of the weight, are now perpendicular under the pressure, and are capable of sustaining the whole. If roads were made perfectly level, and had no holes in them, the wheels of carts might be made without dishing; but if a cart is calculated for a country road, let the wheelwright consider what equivalent he has to give for that very pretty result proceeding from the obliquity of the spokes, or *dishing* of the wheel.

When we return to consider the human thigh-bone, we see that the same principle holds; that is to say, that whilst a man stands on both his legs, the necks of the thigh-bones are oblique to the line of gravitation of the body; but when one foot is raised, the whole body then being balanced on one foot, a change takes place in the position of the thigh-bone, and the obliquity of that bone is diminished; or, in other words, now that it has the whole weight to sustain, it is perpendicular under it, and has therefore acquired greater strength. (See below.)



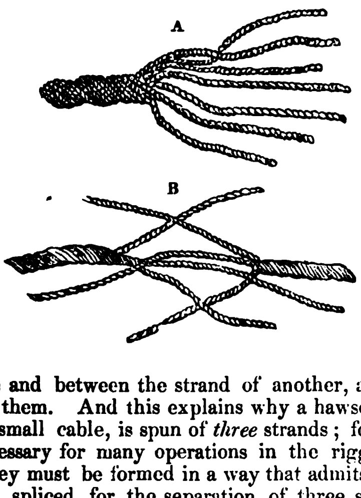
CHAPTER V.

OF THE TENDONS COMPARED WITH CORDAGE.

WHERE nature has provided a perfect system of columns, and levers, and pullies, we may anticipate that the cords by which the force of the muscles is concentrated on the moveable bones must be constructed with as curious a provision for their offices. In this surmise we shall not be disappointed.

To understand what is necessary to the strength of a rope or cable we must learn what has been the object of the improvements and patents in this manufacture. The first process in rope-making, is hatchelling the hemp; that is, combing out the short fibres, and placing the long ones parallel to one another. The second is, spinning the hemp into yarns. And here the principle must be attended to, which goes through the whole process in forming a cable; which is that the fibres of the hemp shall bear an equal strain: and the difficulty may be easily conceived, since the twisting must derange the parallel position of the fibres. Each fibre, as it is twisted, ties the other fibres together, so as to form a continued line, and it bears at the same time a certain portion of the strain, and so each fibre alternately. The third step of the process is making the yarns. Warping the yarns, is stretching them to a certain length; and for the same reason that so much attention has been paid to the arrangement of the fibres for the yarns, the same care is taken in the management of the yarns for the strands. The fourth step of the process is to form the strands into ropes. The difficulty of the art has been to make them bear alike, especially in great cables, and this has been the object of patent machinery. The *hardening*, by twisting, is also an essential part of the process of rope-making; for without this, it would be little better than extended parallel fibres of hemp. In this twisting, first of the yarns, and then of the strands, those which are on the outer surface must be more stretched than those near the centre; consequently, when there is a strain upon the rope, the outer fibres will break first, and the others in succession. It is to avoid this, that each yarn and each strand, as it is twisted or hardened, shall be itself revolving, so that when drawn into the cable, the whole component parts may, as nearly as possible, resist the strain in an equal degree; but the process is not perfect, and this we must conclude from observing how different the construction of a tendon is from that of a rope. A tendon consists of a strong cord, apparently fibrous; but which, by the art of the anatomist, may be separated into lesser cords, and these, by maceration, can be shown to consist of cellular membrane, the common tissue that gives firmness to all the textures of the animal body. The peculiarity here results merely from its remarkable condensation. But the cords of which the larger tendon consists do not lie parallel to each other, nor are they simply twisted like the strands of a rope; they are, on the contrary, plaited or interwoven together.

If the strong tendon of the heel, or Achilles tendon, be taken as an example, on first inspection it appears to consist of parallel fibres, but by maceration these fibres are found to be a web of twisted cellular texture. If you take your handkerchief, and slightly twisting it, draw it out like a rope, it will seem to consist of parallel cords; such is, in fact, so far the structure of a tendon. But, as we have stated, there is something more admirable than this, for the tendon consists of subdivisions, which are like the strands of a rope; but instead of being twisted simply as by the process of hardening, they are plaited or interwoven in a way that could not be imitated in cordage by the turning of a wheel. Here then is the difference,—by the twisting of a rope, the *strands* cannot resist the strain equally, whilst we see that this is provided for in the tendon by the regular interweaving of the yarn, if we may so express it, so that every fibre deviates from the parallel line in the same degree, and, consequently, receives the same strain when the tendon is pulled. If we seek for examples illustrative of this structure of the tendons, we must turn to the subject of ship-rigging, and see there how the seaman contrives, by undoing the strands and yarns of a rope, and twisting them anew, to make his splicing stronger than the original cordage. A sailor opens the ends of two ropes thus;* and places the strand of one opposite and between the strand of another, and so interlaces them. And this explains why a hawser-rope, a sort of small cable, is spun of *three* strands; for as they are necessary for many operations in the rigging of a ship, they must be formed in a way that admits of being cut and spliced, for the separation of three strands, at least, is necessary for knotting, splicing, whipping, mail-



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* A, Strands and Yarns opened.

B, Ends opened and laid for splicing, in a manner exactly like the interlacing of the tendon.

ing, &c., which are a few of the many curious contrivances for joining the ends of ropes, and for strengthening them by filling up the interstices to preserve them from being cut or frayed. As these methods of splicing and plaiting in the subdivisions of the rope make an intertexture stronger than the original rope, it is an additional demonstration, if any were wanted, to show the perfection of the cordage of an animal machine, since the tendons are so interwoven; and until the yarns of one strand be separated and interwoven with the yarns of another strand, and this done with regular exchange, the most approved patent ropes must be inferior to the corresponding part of the animal machinery.

A piece of cord of a new patent has been shown to us, which is said to be many times stronger than any other cord of the same diameter. It is so far upon the principle here stated, that the strands are plaited instead of being twisted; but the tendon has still its superiority, for the lesser yarns of each strand in it are interwoven with those of other strands. It, however, gratifies us to see, that the principle we draw from the animal body is here confirmed. It may be asked, do not the tendons of the human body sometimes break? They do; but in circumstances which only add to the interest of the subject. By the exercise of the tendons, (and their exercise is the act of being pulled upon by the muscles, or having a strain made on them,) they become firmer and stronger; but in the failure of muscular activity, they become less capable of resisting the tug made upon them, and if, after a long confinement, a man has some powerful excitement to muscular exertion, then the tendon breaks. An old gentleman, whose habits have been long staid and sedentary, and who is very guarded in his walk, is upon an annual festival tempted to join the young people in a dance; then he breaks his tendo Achillis. Or a sick person, long confined to bed, is, on rising, subject to a rupture or hernia, because the tendinous expansions guarding against protrusion of the internal parts have become weak from disuse.

Such circumstances remind us that we are speaking of a living body, and that, in estimating the properties of the machinery, we ought not to forget the influence of life, and that the natural exercise of the parts, whether they be active or passive, is the stimulus to the circulation through them, and to their growth and perfection.

CHAPTER VI.

OF THE MUSCLES—OF MUSCULARITY AND ELASTICITY.

There are two powers of contraction in the animal frame—elasticity, which is common to living and dead matter, and the muscular power, which is a property of the living fibre.

The muscles are the only organs which properly have the power of contraction, for elasticity is never exerted but in consequence of some other power bending or stretching the elastic body. In the muscles, on the contrary, motion originates; there being no connexion, on mechanical principles, betwixt the exciting cause and the power brought into action.

The real power is in the muscles, while the safeguard against the excess of that power is in the elasticity of the parts. This is obvious in the limbs and general texture of the frame; but it is most perfectly exhibited in the organs of circulation. If the action of the heart impelled the blood against parts of solid texture, they would quickly yield. When, by accident, this does take place, even the solid bone is very soon destroyed. But the coats of the artery which receive the rush of blood from the heart, although thin, are limber and elastic; and by this elasticity or yielding they take off or subdue the shock of the heart's action, while no force is lost; for as the elastic artery has yielded to the sudden impulse of the heart, it contracts by elasticity in the interval of the heart's pulsation; and the blood continues to be propelled onward in the course of the circulation, without interval, though regularly accelerated by the pulse of the heart.

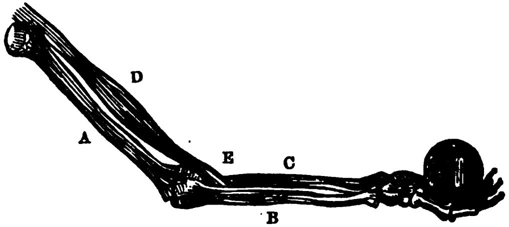
If a steam-engine were used to force water along the ter-pipes, without the intervention of some elastic dy, the water would not flow continuously, but in ks, and, therefore, a reservoir is constructed contain- air, into which the water is forced, against the elasity of the air. Thus, each stroke of the piston is not ceptibly communicated to the conduit-pipe, because intervals are supplied by the push of the compressed . The office of the reservoir containing air is permed in the animal body by the elasticity of the coats the arteries, by which means the blood which flows erruptedly into the arteries has a continuous and uninrupted flow in the veins beyond them.

A muscle is fibrous, that is, it consists of minute eads bundled together, the extremities of which are nected with the tendons which have been described. numerable fibres are thus joined together to form one scle, and every muscle is a distinct organ. Of these tinct muscles for the motions of the body there are less than 436 in the human frame, independent of se which perform the internal vital motions. The tractile power which is in the living muscular fibre, sents appearances which, though familiar, are really most surprising of all the properties of life. Many empts have been made to explain this property, someies by chemical experiment, sometimes on mechanical nciples, but always in a manner repugnant to common se. We must be satisfied with saying, that it is an lowment, the cause of which it would be as vain to estigate as to resume the search into the cause of vitation.

The ignorance of the cause of muscular contraction s not prevent us from studying the laws which regu- it, and under this head are included subjects of the hest interest; which, however, we must leave, to sue the mechanical arrangement of the muscles.

Since we have seen that there are 436 distinct muscles the body, it is due to our readers to explain how they associated to effect that combination which is neces- y to the motion of the limbs and to our perfect enjoy- nt. In the first place, the million of fibres, which constitute a single muscle, are connected by a tissue of nerves, which produce a union or sympathy amongst them, so that one impulse causes a simultaneous effort of all the fibres attached to the same tendon. When we have understood that the muscles are distinct organs of motion, we perceive that they must be classed and associated in order that many shall combine in one act; and that others, their opponents, shall be put in a state to relax, and offer no opposition to those which are active. These relations can only be established through nerves, which are the organs of communication with the brain, or sensorium. The nerves convey the will to the muscles, and at the same time they class and arrange them so as to make them consent to the motions of the body and limbs.

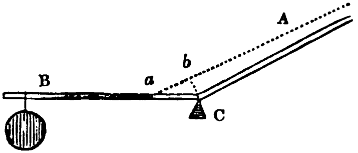
On first looking to the manner in which the muscles are fixed into the bones, and the course of their tendons, we observe everywhere the appearance of a sacrifice of mechanical power, the tendon being inserted into the bone in such a manner as to lose the advantage of the lever. This appears to be an imperfection, until we learn that there is an accumulation of vital power in the muscle in order to attain velocity of movement in the member.



The muscle D, which bends the fore-arm, is inserted into the radius E, so near the fulcrum, or centre of motion in the elbow joint, and so oblique that it must raise the hand and fore-arm with disadvantage. But, correctly speaking, the power of the muscle is not sacrificed, since it gains more than an equivalent in the rapid and lively motions of the hand and fingers, and since these rapid motions are necessary to us in a thousand familiar actions; and to attain this, the Creator has given sufficient vital power to the muscles to admit of the sacrifice of the mechanical or lever power, and so to provide for every degree and variety of motion which may answer to the capacities of the mind.

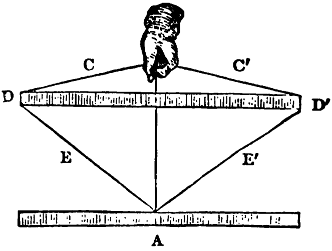
If we represent the bones and muscles of the fore-arm by this diagram, we shall see that power is lost by the inclination of the tendon to the lever, into which it is inserted. It represents the lever of the third kind, where the moving power operates on a point nearer the fulcrum than the weight to be moved.

Here A represents the muscle, B the lever, and C the fulcrum. The power of the muscle is not represented by the distance of its insertion *a*, from the fulcrum C. The line which truly represents the lever must pass from the centre of motion, perpendicularly to the line of the tendon, viz., C, *b*. Here, again, by the direction of the tendon, as well as by its actual attachment to the bone, power is lost and velocity gained.



We may compare the muscular power to the weight which impels a machine. In studying machinery, it is manifest that weight and velocity are equivalent. The handle of the winch in a crane is a lever, and the space through which it moves, in comparison with the slow motion of the weight, is the measure of its power. It the weight, raised by the crane, be permitted to go down, the wheels revolve, and the handle moves with the velocity of a cannon-ball, and will be as destructive if it hit the workman. The weight here is the power, but it operates with so much disadvantage, that the hand upon the handle of the winch can stop it: but give it way, let the accelerated motion take place, and the hand would be shattered which touched it. Just so the fly-wheel, moving at first slowly, and an impediment to the working of a machine, at length acquires momentum, so as to concentrate the power of the machine, and enable it to cut bars of iron with a stroke.

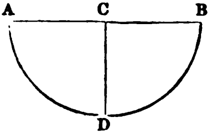
The principle holds in the animal machinery. The elbow is bent with a certain loss of mechanical power; but by that very means, when the loss is supplied by the living muscular power, the hand descends through a greater space, moves quicker, with a velocity which enables us to strike or to cut. Without this acquired velocity, we could not drive a nail: the mere muscular power would be insufficient for many actions quite necessary to our existence.



Let us take some examples to show what objects are attained through the oblique direction of the fibres of the
e, and we shall see that here, as well as by the
of attachment of the entire muscle, velocity is at-
by the sacrifice of power. Suppose these two
of wood to be drawn together by means of a
ut that the hand which pulls, although pos-

sessing abundant strength, wants room to recede more than what is equal to one third of the space betwixt the pieces of wood; it is quite clear, that if the hand were to draw direct on the cord A, B, the point A would be brought towards B, through one third only of the intervening space, and the end would not be accomplished. But if the cord were put over the ends of the upper piece, C, D, E, and, consequently, directed obliquely to their attachment at A, on drawing the hand back a very little, but with more force, the lower piece of wood would be suddenly drawn up to the higher piece, and the object attained. Or we may put it in this form:—If a muscle be in the direction of its tendon, the motion of the extremity of the tendon will be the same with that of the muscle itself: but if the attachment of the muscle to the tendon be oblique, it will draw the tendon through a greater space; and if the direction of the muscle deviate so far from the line of the tendon as to be perpendicular to it, it will then be in a condition to draw the tendon through the greatest space with the least contraction of its own length.

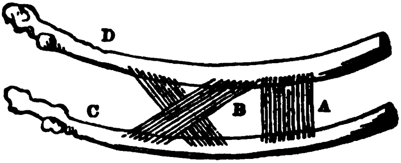
Thus, if A, B be a tendon, and C, D a muscle; by the contraction of C to D the extremities of the tendon A, B



will be brought together, through a space double the contraction of the muscle. It is the adjustment, on the same principle, which gives the arrow so quick an impulse from the spring of the bow, the extremities of the bow drawing obliquely on the string.

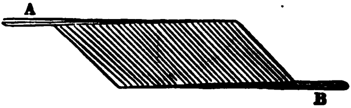
To free breathing, it is necessary that the ribs shall approach each other, and this is performed by
tercostal muscles (or muscles playing betwe
and now we can answer the question, Why
of these muscles oblique?

Let us suppose this figure to represent two ribs wit
intervening muscles. If the fibres of the muscle we
the direction A, across, and perpendicular to the r



and if they were to contract one-third of their l
they would not close the intervening space—they w
not accomplish the purpose. But being oblique, a
although they contract no more than one-third of
length, they will bring the ribs C, D together. B
obliquity of the intercostal muscles, they are enab
expand the chest in inspiration, in a manner which
not be otherwise accomplished.

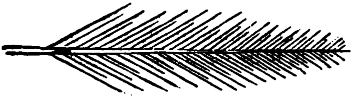
In the greater number of muscles the same pri
directs the arrangement of the fibres; they exch
power for velocity of movement, by their obliq
They do not go direct from origin to insertion,
obliquely, thus, from tendon to tendon :—



Supposing the point A to be the fixed point, t
fibres draw the point B with less force, but throug
larger space, or more quickly than if they took t
course in direct lines; and by this arrangement o
the freedom and extent of motion in our limbs

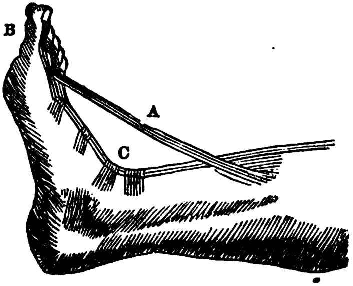
the muscles must be strengthened by additi
of fibres, because they are oblique; since by t
thing of their force of

ıerefore it is, we must presume, that we find them
ouble row, making what is termed the *penniform*
e, thus,—



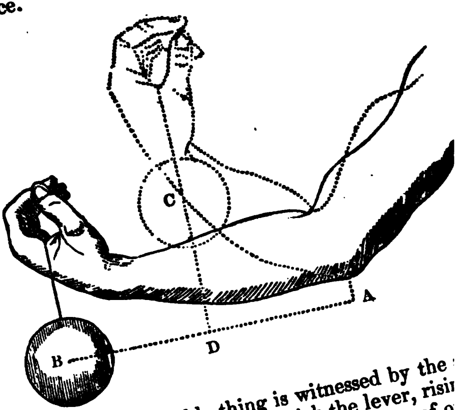
ɔmetimes the texture of the muscle is still further
ɔunded by the intermixture of tendons, which permit
onal series of fibres; and all this for the obvious
se of accumulating power, which may be exchanged
ːlocity of movement.

ɔ may perceive the same effect to result from the
ː of the tendons, and their confinement in sheaths,
ːthened by cross-straps of ligament. If the
n, A, took the shortest course to its termination at



vould draw up the toe with greater force; but then
e would lose its velocity of movement. By taking
rection C, close to the joints, the velocity of motion
ıred, and by this arrangement the toes possess their
:, and the fingers their lively movements. We may
this opportunity of noticing how the mechanical
ition is diminished as the living muscular power is

1. For example, in lifting a weight, the length ver of resistance will be from the centre of the oint, A, to the centre of the weight, B. As scles of the arm contract, they lose something power; but in a greater proportion is the me- al resistance diminished, for when the weight is to C A D, it becomes the measure of the lever of nce.



A more admirable thing is witnessed by the —we mean the manner in which the lever, risi ing, is carried beyond the sphere of action of o muscles, and enters the sphere of activity of ot this adaptation of the organs of motion is fine to the mechanical resistance which may ari form or motion of the bones. In short, whe template the million of fibres which constitut or the many muscles which combine to the the limb, nothing is more surprising and a the adjustment of their power so as to bala resistance, arising from the change of levers.

he animal body, there is a perfect relation pre-
betwixt the parts of the same organ. The mus-
fibres forming what is termed the belly of the
, and the tendon through which the muscle pulls,
o parts of one organ; and the condition of the
n indicates the state of the muscle. Thus jockeys
er the qualities of a horse by its sinews or tendons.
nost approved form in the leg of the hunter, or
ey, is that in which three convexities can be dis-
shed,—the bone; the prominence of the elastic
nt behind the bone; and behind that the flexor
ns, large, round, and strong. Strong tendons are
ed for strong muscles, and the size of these indi-
he muscular strength. Such muscles, being power-
xors, cause high and round action, and such horses
e to ride; their feet are generally preserved good,
to the pressure they sustain from their high action.
his excellence in a horse will not make him a
ite at Newmarket. The circular motion cannot be
wiftest; a blood-horse carries his foot near the
d. The speed of a horse depends on the strength
loins and hind quarter; and what is required in the
egs is strength of the extensor tendons, so that the
ay be well thrown out before, for if these tendons
t strong, the joints will be unable to sustain the
t of his body, when powerfully thrown forward, by
xertion of his hind-quarters, and he will be apt to
with his nose to the ground.

e whole apparatus of bones and joints being thus
ally constituted by Nature in accurate relation to
uscular powers, we have next to observe, that this
tus is preserved perfect by exercise. The tendons,
eaths in which they run, the cross ligaments by
they are restrained, and the *bursæ mucosæ* *
are interposed to diminish friction, can be seen in
tion only when the animal machinery has been kept

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hese *bursæ mucosæ* (mucous purses) are sacs containing
cating fluid. They are interposed wherever there is
pressure or friction, and answer all the purposes of
n-wheels in machinery.

in full activity. In inflammation, and pain, and
sary restraint, they become weak; and even
ment, and want of exercise, without disease, will
imperfections. Exercise unfolds the muscular
producing a full bold outline of the limbs, at the
time that the joints are knit, small, and clean. In
loins, thighs, and legs of a dancer we see the
system fully developed; and when we turn our
to his puny and disproportioned arms, we acknowl
the cause—that, in the one instance, exercise has
duced perfection, and that, in the other, the want
has occasioned deformity. Look to the legs of a
Irishman travelling to the harvest with bare feet:
thickness and roundness of the calf show that
foot and toes are free to permit the exercise of
muscles of the leg. Look, again, to the leg of our
lish peasant, whose foot and ankle are tightly laced
shoe with a wooden sole, and you will perceive, from
manner in which he lifts his legs, that the play of
ankle, foot, and toes is lost, as much as if he were
stilts, and, therefore, are his legs small and shapeless.

And this brings us naturally to a subject of some interest at present: we mean the new fashion of exercising
our youth in a manner which is to supersede dancing,
fencing, boxing, rowing, and cricket, and the natural
pulse of youth to activity.

By this fashion of training to what are termed
nastics, children at school are to be urged to feats
strength and activity, not restrained by parental
rity, nor left to their own sense of pleasurable exertion
They are made to climb, to throw their limbs over a
to press their foot close to their hip, their knees close
their stomach; to hang by the arms and raise the body
—to hang by the feet and knees,—to struggle against
each other, by placing the soles of their feet in
and to pull with their hands. No doubt, if
s be persevered in, the muscular powers will
developed. But the first question to be
is the safety of this practice. We have seen
es, by such training, acquire

rength and prominence of muscles; but by this unna ral increase of muscular power, through the exercise recommended, he became ruptured on both sides. he same accident has happened to boys too suddenly it on these efforts.

It is proper to observe, that when the muscular power thus, we may say, preternaturally increased, whether the instance of a race-horse, an opera-dancer, or a pupil the Calisthenic school, it is not merely necessary to it them on their exercises gradually in each successive son, but each day's exertion must be preceded by a earisome preparation. In the great schools, like that at ockholm, the master makes the boys walk in a circle; en run, at first gently; and so he gradually brings em into heat, and the textures of their frame are comsed to that state of elasticity and equal resistance, as ell as to vital energy, which is necessary for the safe splay of the greater feats of strength and activity. This ution in the public exercises is the very demonstration the dangers of the system. The boys will not be ays under this severe control, and yet it is important their safety.

Ve may learn how necessary it is to bring the animal em gradually into action from the effects of very mote exercise on a horse just out of the dealer's hands. purchaser thinks he may safely drive him ten miles, ware that the horse has not moved a mile in a week, he consequence is, inflammation and congestion in ngs. The regulation in the army has been made on wledge of these facts. When young horses are it from the dealer they are ordered to be walked r a-day the first week, two hours a-day the second three hours a-day in the third week. They are to ued by walking, but they must not be sweated in ercise. Horses for the turf, under three years training for the Derby, are brought very slowly to ercise, beginning with the lounge; then a very ight is put upon them, and that gradually in- Indeed, nothing can better show the effects of exercise in perfecting the muscular action than the consequence of the loss of one day's training. It will bring the favourite to the bottom of the list, and that without any suspicion of lameness, but from a knowledge of the fact, that even such a slight irregularity in his training will have a sensible effect on his speed. Shall the possibility of pecuniary loss excite the jockey to more care for his horse than we, in our rational and humane attention to the education of our youth, pay to their health and safety?

In reflecting on these many proofs of design in the animal body, it must excite our surprise that anatomy is so little cultivated by men of science. We crowd to see a piece of machinery or a new engine, but neglect to raise the covering which would display in the body the most striking proofs of design, surpassing all art in simplicity and effectiveness, and without any thing useless or superfluous.

A more important deduction from the view of the animal structure is, that our conceptions of the perfection and beauty in the design of nature are exactly in proportion to the extent of our capacity. We are familiar with the mechanical powers, and we recognise the principles in the structure of the animal machine; and in proportion as we understand the principles of hydrostatics and hydraulics, are able to discern the most beautiful adaptation of them in the vessels of an animal body. But when, in our further progress in anatomy, it is necessary that we should study a matter so difficult as the theory of life, imperfect principles or wrong conceptions distort and obscure the appearances: false and presumptuous theories are formed, or we are thrown back in disappointment into scepticism, as if chance only could produce that, of which we do not comprehend the perfect arrangement. But studies better directed, and prosecuted in a better spirit, prove that the human body, though deprived of what gave it sense and motion, is still a plan drawn in perfect wisdom.

A man possessed of that humility which is akin to true knowledge, may be depressed by too extensive a survey of the frame of nature. The stupendous changes which the geologist surveys — the incomprehensible magnitude of the heavenly bodies moving in infinite space, bring down his thoughts to a painful sense of his own littleness: "to him the earth with men upon it will not seem much other than an ant-hill, where some ants carry corn, and some carry their young, and some go empty, and all to and fro—a little heap of dust." *

He is afraid to think himself an object of Divine care; but when he regards the structure of his own body, he learns to consider space and magnitude as nothing to a Creator. He finds that the living being, which he was about to contemn, in comparison with the great system of the universe, exists by the continuance of a power, no less admirable than that which rules the heavenly bodies; he sees that there is a revolution, a circle of motions no less wonderful in his own frame, in the microcosm of man's body than in the planetary system; that there is not a globule of blood which circulates, but possesses attraction as incomprehensible and wonderful as that which retains the planets in their orbits.

The economy of the animal body, as the economy of the universe, is sufficiently known to us to compel us to acknowledge an Almighty power in the creation. What would be the consequence of a further insight—whether it would conduce to our peace or happiness—whether it would assist us in our duties, or divert us from the performance of them, is very uncertain.

* Bacon.

PART II.

SHOWING THE APPLICATION OF THE LIVING P

AMONGST the least informed people, and in re lages, there are old saws and rules regarding sickness, and wounds, which might be thought from mere experience; but they are, on the for the most part, the remains of forgotten the opinions, laid down by the learned of former da tions of knowledge, it would appear, confined a select part of society, are, in the progress of t fused generally, and may be recognised in the a of the poor. These are traced to their source the curious few, who like to read old books, an serve how that which is originally right, becomes prejudice and ignorance, distorted and fantastica

If a very little exact knowledge of the stru our own frames were more generally diffused would be advanced, empirics could hardly maint influence, and medical men might have a farthe to desire professional eminence.

Men suppose that the knowledge of their ow must be a science locked up from them, becau language in which it is conveyed; or they ta their thoughts from it, as from the contemp danger, unwilling to survey the slight ties by wh hold their lives. They are like persons for the at sea, who shudder to calculate how many circu must concur to speed the frail vessel on its voy how little is between them and the deep. It a mean and timid spirit that shuts out from our plation the finest proofs of Divine Providen len's treatise on the uses of the parts of the hum was composed as a hymn to the Creator, and abounds in demonstrations of a Supreme Cause; and when Cicero desires to prove the existence of the Deity from the order and beauty of the universe, he surveys the body of man, deeming nothing more godlike, as marking man's superiority to the brutes, than the privilege of contemplating his own condition, since it teaches him the ways of Providence, from a knowledge of which come piety and all the virtues.

Although we are writing under the title of Animal Mechanics, the reader must be aware that we cannot proceed much farther, on mechanical principles alone. At least, before we have it in our power to illustrate particular parts of the animal frame, by reference to those principles, we must have the proofs before us that we are considering a living body. It is the principle of *life* which distinguishes the studies of the physiologist from the other branches of natural knowledge. To lose sight of this distinction is to tread back the path, and to engage once more in the vain endeavour to explain the phenomena of life on mechanical principles. We have taken mechanics in their application to mechanical structure in the living body, because they give obvious proofs of design, and in a manner that admits of no cavil. Yet, although those proofs are very clear in themselves, they are not so well calculated to warm and exalt our sentiments as these which we have now to offer in taking a wider view of the animal economy.

In entering on the second department of this treatise, the reader may be startled at the subjects of discussion; but this comes also from ignorance of their nature. Much may be learned from the observation of things familiar. Their perpetual recurrence banishes reflection respecting them, but it is the business of philosophy to make us alive to the importance of that which we have been accustomed to from childhood, and have, therefore, long ceased to observe with attention.

In the first chapter of this second part we shall continue to examine the operations of the animal body, independently of the agency of the living property. We shall consider it as a mere hydraulic machine. Following the blood in its circle through cisterns and conduit pipes, we shall point out the application of the principles of this science as we formerly did those of mechanics, and so arrive at the like conclusions by a different course. And as we before found every muscular fibre adjusted with mechanical precision, so now we shall find every branch of an artery, or of a vein, taking that precise course and direction which the experience of the engineer shows to be necessary in laying the pipes of an engine.

Having thus surveyed the mechanical operations of the animal body, and the course of the fluids conveyed through it, on hydraulic principles, we shall consider ourselves as having advanced through the meaner to the higher objects of inquiry, and proceed to show how the principle of life bestows different endowments on the framework; how motion originates in a manner quite different from that produced by mechanical forces; how the sensibilities animate the living properties of action; how the different endowments of life correspond with each other, and exhibit power and design in a degree far superior to any thing that we observed in the mechanical adjustment of the parts, or the circulation of the fluids.

CHAPTER I.

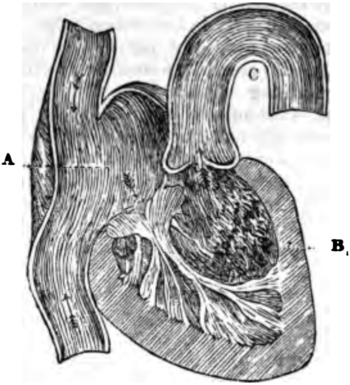
THE CIRCULATION OF THE BLOOD, UPON THE PRINCIPLES OF HYDRAULICS.

In tracing the course of the circulation of the blood, it is natural to inquire how far the system of reservoirs, pipes, and valves, which form the apparatus for conveying it, are constructed on the principles of hydraulics.

We find this difficulty in the outset, that the vessels containing the blood are not rigid, like those the engineer employs in erecting hydraulic machinery. Instead of resembling pipes which convey water, and which receive the force of gravitation on them, they have both elasticity and an appropriate living power. The artery, the tube which conveys the blood out from the heart to the body, has a property of action in itself. Its elasticity and muscular power must derange those influences which we study in pure hydraulics.

There is to be found, notwithstanding, a great deal that is common to both, when we compare the tubes of an animal body with the hydraulic engine; the capacity of the vessels; the increase, or diminution, of their calibres; their curves; the direction of their branches; —all these ought still to be on the same principles on which experience has taught men to form conduit pipes. We ought not to be indifferent to these proofs of design, because we acknowledge that an infinitely superior power is brought into operation in the animal body, and which is necessary to the circulation of the blood. It renders the inquiry more difficult, but it does not obscure the inferences drawn from the consideration of the whole subject.

We shall first present to our readers the simplest form of the Heart. It is not necessary to detail the complicated structure of the human heart, whe fact, two hearts are combined; the fibres of th continued into the fibres of the other, and the twisting round one another so as to present the which is familiar to everybody. Although the four intricate cavities, seven tubes conveying the into them, and two conveying it out of them, we for the purpose of considering the forces circulati blood, and comparing the living vessels with pipe sent the heart and vessels as simple; yet, with truth, being, in fact, the heart and vessels of ani more simple structure.



The action of the heart is this: the blood return the body by veins into the sinus or auricle,* A, and di it: this sinus is surrounded with muscular fibres; distention or elongation of these fibres they are ex and the sinus contracts and propels the blood into the ventricle, B. The ventricle is more muscular; it is, in fact, a powerful hollow muscle; it is excited by the distention, and contracts and propels the blood into the artery, C.

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* Auricle, from *auricula*, the flap of the ear, is a given to the sinus, because a corner of it hangs over dog's ear.

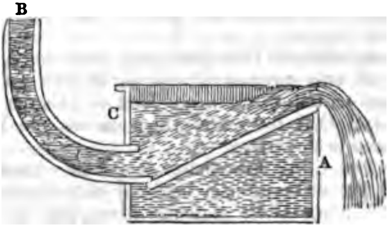
We understand then that every heart must, at least, consist of two cavities alternating in their action; that the vessel which carries the blood to them is called a vein; and that the vessel which carries the blood out from them is the artery.

The first thing that strikes a person examining the heart is the extraordinary intricacy of the cavities, from the interlacing of its muscular fibres, and he naturally says that they appear ill calculated for conveying a fluid through them. There is an attraction between fluids and solids, he might observe, and this attraction is increased by the extension of the surfaces of the pillars and cords which he sees in the interior of the heart.

We must remind him that the blood is coming back from the body, having performed very different offices in different parts, and has parted with different properties in the several organs it has supplied. There is in that stream of blood which enters through the vein a new supply of fluid which has come by digestion, the material for making fresh blood, as well as that which has run the circle. These two fluids must be thoroughly mixed together, and, no doubt, this is one of the offices provided for by the intricacy of the interior of the heart.

Again, looking to the recesses of the cavities formed between the fleshy columns, and behind the valves, we might suppose that the blood would remain there stagnant. There are cavities or recesses too in the remote parts of the circulating vessels, where we might suspect that the influence of the stream would not be felt, and a stagnation might take place. But there is attraction between the particles of fluids as well as between the fluids and their containing tubes. Let us see then how, in this figure, a stream of water carried through a cistern of water will, by its friction, draw after it the water in

the cistern, and carry it above its natural level, and
the side of the vessel.



The stream entering the reservoir, A, by the pipe
carries with it all the water, C, which stands above
level of its upper surface. By this we see that
stream of blood entering into the heart, even if its c
ties were not emptied at each pulse, as some cont
they are, would draw out the blood from its recesses
that no part could remain stagnant, but, on the contr
all would be carried in eddies round the irregularities
they took the direction of the great artery, in which
would be perfectly combined.

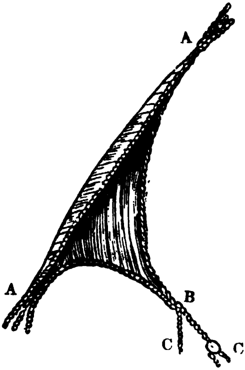
The next thing to be noticed partakes of the natur
a mechanical provision—we mean the action of
valves.

We must here remark, that the opening into the
tricle is very different from that which leads out of
the latter being much smaller. Medical writers desc
this as if it were nothing to them, and a mere accid
But it must be recollected, that a stream of water en
ing a reservoir, is in a very different condition from
which is going out of it; it is on this principle that
mouths (*ostia* is the anatomical term) of the ventricle
differently formed, and it is this difference which m
the structure of the valves which guard those passage
dissimilar and so appropriate. Without attention to
we should follow our medical authorities, and call
variety in the mechanical adaptation a mere playful

in nature. It is more agreeable to us, to see a precision of design visible at the first step of this inquiry.

The valves of the heart are regular flood-gates which close the openings against the retrograde motions of the blood. They are not all of the same mechanical construction; and their difference deserves the reader's attention as proving design in this hydraulic machinery.

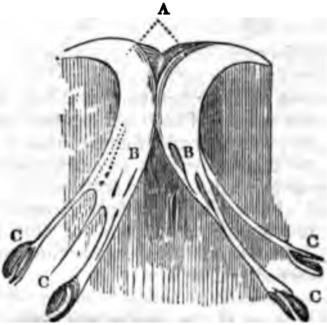
The valve which we have first to describe closes the opening betwixt the auricle or sinus and the ventricle, and prevents the action of the ventricle propelling the blood back again into the auricle.



It is a web or membrane, resembling a sail, when bagged by the wind. The blood catches the margin of this membrane, and distends it as the wind does the stay-sail, or jib, of a vessel, which it much resembles, being triangular and pointed. There are three of these membranes, and the valve is called *tricuspid*, or three-pointed. Three membranes then, of this kind, combining and being floated back upon the mouth of the opening, effectually close it.

The illustration of the action of these valves by a sail is so perfect, that if the reader will have patience to attend to those little contrivances which the mariner finds necessary for strengthening his canvass, and giving to it the full influence of the wind, he will have an accurate idea of the adjustment of these floating valves.

To carry on the comparison—one edge of the stay-sail is extended upon the stay A A, and tied to it by *hanks*. The edges of the sails called the *leeches* have a *bolt-rope* run along them; and on the edge where it is attached the canvass is strengthened by being hemmed down or tabled. In the same way as the foot of the sail, or lower margin, is strengthened with the bolt-rope, just so are the valves strengthened at their edges and their corners. Where the two ropes join in the loose corner of the sail, they form a clue—a loop to which tackle is attached; the valve has such a corner, so strengthened, and has a cord attached. The corners of the sail are strengthened by additional portions of canvass called patches; so are the valves strengthened where their tendons are infixed. To the corner or clue, B, ropes are attached which are called the *sheets*, C C. These being drawn tight, spread out the foot of the sail to one side or the other, according to the direction of the wind, and the tack the ship is on; the valves have also their tackle; and, in short, we shall find a resemblance to all the parts of a sail in the valves of the heart.



ne edge of the triangular valve is tied to the margin
he opening, as one of the leeches of the sail is at-
ed to the stay; the opposite corner is loose, and
ts, as the sail does in tacking, until the blood, bear-
against it as the wind bears against the sail, bags and
ends it; the corner is then held down by tendons,
there are cords attached to the corner of the valve, as
as to the corner of the sail. These the anatomist
cordæ tendineæ, B B, which in their office have an
t resemblance to the ropes called the sheets of the
They are delicate tendons attached to the margin
he valve, and they prevent the margin from being
ied back into the auricle.

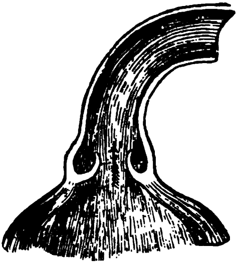
ere we find a very beautiful muscular apparatus
ch is necessary to the perfect adjustment of these
ls. The cords are attached to small muscles called
mnæ carneæ, C C, or fleshy columns, which at their
r extremities are incorporated with the muscular
of the ventricle itself. The use of these muscles is
to be explained. Had the tendinous cords of the
es been tied to the inside of the wall of the ventricle,
out the intervention of these muscles, as the walls of
cavity approach each other during their contraction,
tendinous cords would have been let loose, and the
gins of the valves carried back into the auricle. But
the intervention of these muscles, they are pulled
n and shortened in proportion as the sides of the
ty approach each other.

n the whole, then, we perceive that this apparatus,
ch is as intricate as the rigging of a ship, consists of
riety of fleshy columns and cords, many of which, in
, run across the cavity of the ventricle.

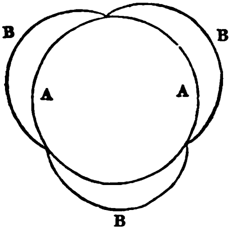
e are about to exhibit another form of a valve, much
pler, and yet we are bound to believe equally ef-
ual: which tends to support the opinion expressed
e, that besides preventing the retrograde motion of
lood, this intricate apparatus of the ventricle is in-
d more effectually to agitate and to mix the different
ns.

the root or origin of the great artery, called the

Aorta, there is a firm ring to which the valves now to be described are attached. The necessity of this will appear evident, since, if the ring could be stretched by the force of the heart's action, the valves or flood-gates would not be sufficient to close the passage; their conjoined diameters would not equal that of the artery which they have to close. These valves are three in number: they are little half-moon-shaped bags of thin membrane, which are thrown up by the blood passing out from the ventricle, but by the slightest retrograde movement of the blood their margins are caught, and then, being distended or bagged, they fall together, and close the passage. There are some curious little adjuncts to these valves, which ought to be explained, as showing the accuracy of the mechanical provision.

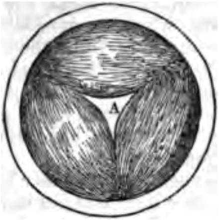


When the margin of the valve is thrown up by the blood passing out of the heart, it is not permitted to touch or fall flat upon the side of the artery, for if it did, it would not be readily caught up by the blood that flows back; there is therefore a little dilatation of the coats of the artery behind each valve by which, although the margins of the valve be distended to the full circle, they never cling to the coats. These valves, then, are never permitted to fall against the coats of the artery, and therefore they are always prepared to receive the motion of the refluent blood.

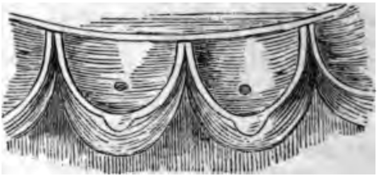


Let this figure represent a transverse section of the root of the aorta, A A, the inner circle is the margin of the three valves thrown up to let the blood pass. B B B are three semicircular bags formed by the dilatation of the coats of the artery at this part, receding from the margin of each of the valves—consequently, in such a manner as to leave a space between the valves and the sides of the vessel.

To strengthen the valves, a tendon runs along their margin like the bolt-rope or foot-rope along the edge of a sail, and these ligaments are attached to the side of the artery, and give the valve great strength.



These valves, we have said, are semilunar; consequently, when they fall together, there must be a space, A, left between them. If we put the points of the thumb, fore and middle fingers, together, there is a triangular space left between them; such a space between the convexities of the three valves would be a defect.



The artery open, and the semi-lunar valves, like little bags, attached to the inside.

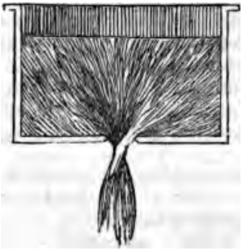
Three little bodies like tongues are therefore attached to the middle of the margin of each valve, and these falling together, when the valve is shut down, perfect the septum and prevent a drop of blood passing backwards.

The valves have no power of accelerating the motion of the blood; they only prevent its retrograde motion, and cause the whole power of the heart to be employed in directing the blood forwards in the course of the circulation. But when they are ruptured, when the valve first described is rent, or the cordæ tendineæ are broken, then the membrane, which we have said is like a sail, is carried back from the second into the first cavity. It is like the sail torn from the sheets and flying out before the wind: the effect is terrible: the pulse of the heart, the whole force of which should be given to carry the blood forwards in the arteries, has half its force directed backwards upon the veins.

In the same manner the semilunar valves in the root of the aorta may have their margins torn. We have described the margin of these valves to be strengthened by a tendon or cord run along their edge, like the rope which is sewed to the edge of a sail. There is an obvious intention in strengthening the valve here; but when textures of this kind become impaired in the human frame, this may give way and be torn, and then 'eaction of the artery, when the heart has given its e, is lost; for, instead of impelling the blood fors, the blood runs backwards into the heart. The : of these accidents is extreme debility of circulation, symptoms varied according as the defect falls on the lation through the lungs or through the body—that hether on the right or the left heart of man. But accidents are rare, and never take place until dishas impaired he strength of what we may call the e of the valve.

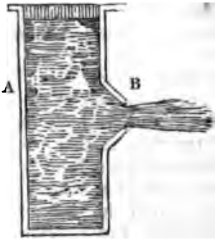
ıe next remark is founded more directly on the hyic principle.

ıis ring and these valves at the beginning of the great y imply a certain constriction, or diminution of the at this part; and we have now to show that such ıtraction of the tube at this precise part does not diıh the diameter of the column of blood. This appears ıconsistency; but if a stream of water flow from a 'n, through a hole in that cistern, the column of : will be diminished at a certain point of its exit.



ıe water flowing through the bottom of the cistern be represented by converging lines; and their united 's impelling the stream forward, contract it just be. the exit—the *Vena Contracta.* Nature, taking ntage of this law, has constructed the narrow ring h we *have shown is* necessary to the accurate adjustment of the valve, at the precise part where the blood, issuing from the cavity of the ventricle, is necessarily contracted to the smallest space. The column of blood would be contracted at this point, even if there were no coats of the artery to confine it there.

We had thought of this as a thing indicated by reasoning, but we find that an appropriate experiment has been made which proves it.



A being the side of a reservoir, and B a short tube giving issue to the water, it will deliver as much water by this conical constructed mouth, as if the tube were of equal diameter with the hole in the reservoir. The reader will perceive how satisfactorily this indicates what is designed by the difference in the size of the mouth of the ventricle which gives entrance, and that which gives issue to the blood.

With a view to explain the motion of fluids in tubes, and finally the motion of the blood in the blood-vessels, let us consider what takes place in the motion of the column of water which is not contained in a tube.

When water is poured out, and descends in an uninter-
ted stream, the column contracts as it descends, until
acquired such a velocity, that the atmosphere op-
t and scatters it; we do not mean the contraction il-
ed by the figure in p. 239, but that gradual diminu-
he diameter of the stream, owing to the height from
t falls. We apprehend that this is on the principle,

at falling bodies are accelerated as the square root of e height from which they fall. The stream being ore rapid at its lower part, is necessarily smaller in iameter, until, having acquired considerable velocity, e resistance of the atmosphere separates its filaments, nd it becomes broader again.

A very different appearance is presented in a jet 'eau; here the ascending stream widens as it ascends. he explanation of this we conceive to be, that the fluid retarded as it mounts, and that the stream propelled om below is forced between the filaments* of the column above, and disperses them, so as to give the column a conical form.

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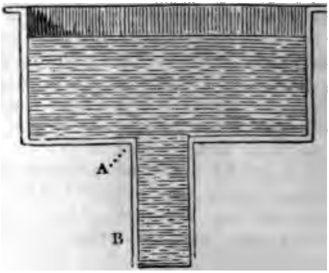
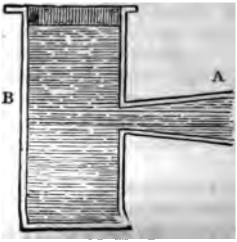
* Those who treat of hydraulics divide a column of water to ideal lesser columns, which they call filaments, with a ery different meaning from the fibres of the anatomist.



This reservoir will be emptied more rapidly if, instead of a hole in the bottom at A, the water be discharged by a tube, A B, of the diameter of the hole.—Here the column of water being perpendicular, it will be accelerated at its lower part; but instead of diminishing its diameter, as it would do, if not confined by a tube, it will draw an additional volume of water down, and accelerate the discharge.

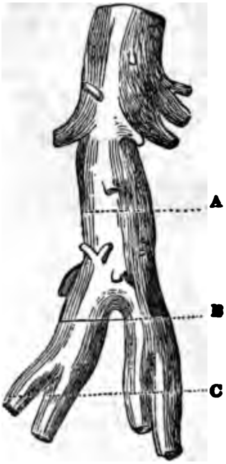
It will be very different if the force be altogether from behind, as when water is propelled into a horizontal tube.

The tube A being conical, will discharge more fluid from the reservoir B than if it had been of equal length,



liameter throughout the same as at its commence-Because, as it appears to us, the weight of the ng column being the force, and this operating as ergo, it is like the water propelled from the jet id the gradual expansion of the tube permits the rom behind to force itself between the filaments, erses them without producing that pressure on s of the tube which must take place where it is m calibre. These principles will give great in- the following fact.

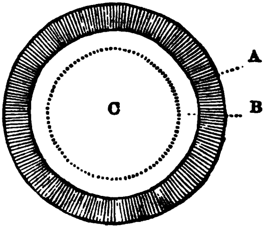
elebrated John Hunter took great pains to prove artery had its diameter enlarged as it proceeded e heart, and that the areas of the branches of y were greater than the diameter of the parent



to say, the section of the trunk at A was not as the two sections at B, taken together; that sections at B taken together, were not so great as

the four sections at c; that the conjoined di
therefore, of the branches of an artery were gre
the diameters of the artery itself. This fact h
sometimes expressed by saying that the artery w
with its apex in the heart.

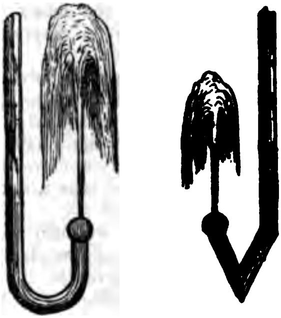
When we stand by a rapid river, we can perc
the surface of it is not level. The stream is rap
middle, and there the water is highest. The f
the water against the bottom and the sides re
stream, whilst the greater velocity of the curre
centre draws the water to it, which is the rea
elevation there.



For the same reason, if an engineer estimate
city of fluid to be delivered through a tube wi
mating the friction of the sides, he will be di
in the result of his calculation; for, as the wa
river is delayed by the bottom and sides, so is
in the tube retarded by the attraction or frictio
the water and the tube. And, if we can ima
tion representing the tube and the flowing wa
be the solid tube, B the water retarded or arres
friction against the tube, and the space c, w
inner circle, would represent that part of the str
is in uninterrupted flow. The engineer will
tube larger than would be necessary, w
ttraction nor friction between the solid
rther appear that the smaller the cali
traction or friction will b

ater. Does not this explain the anatomical we have been contemplating, that the area of r branches is comparatively larger than the which they are derived?

neficial effects result from this; for we must it the blood-vessels of the body are reservoirs conduit pipes. A man of middling stature has e pounds of blood in his circulating vessels: if s did not enlarge as they receded from the e would be no place for the deposit of this tity of blood. The advantages, then, of this form are, first, that a quantity of blood neces- economy is contained within the vessels; and, that the blood is more easily urged forwards ion of the heart. The reader will not now be n learning that a pipe of a conical form, that ng as it proceeds, gives the least interruption of water from a reservoir.



flowing in a tube will be retarded by any sudden ne tube. If the ajutage of a jet d'eau have not nd uniform sweep where it is turned, the jet of not reach the height which it ought to do by of the height of the reservoir of water from lescends—it will go higher from the tube A than

a. This circumstance explains the uniform and olic curve which the great artery of the body takes t ascending from the heart. It explains also why the hes of the great artery go off at different angles, ling to their distance from the heart, or, in other s, why they pass off at smaller angles with the stream urther the artery recedes from the heart.

the distribution of water-pipes, it is very necessary end to the angle at which the small pipe is attached greater one, not only because a pipe being bent tly causes loss of motion from the impulse of the against the side, but also from another well-known f hydraulics.

a pipe be fixed into another so as to join it at an contrary to the direction of the stream, the dis- e into that lateral branch from the larger tube will nly be much smaller than we might estimate by the eters of the tubes, but, in certain circumstances, it discharge nothing at all; nay, on the contrary, the would be drawn from the lesser tube into the er, until the lesser tube be emptied, and air be d in.

rnouilli found that when a small tube B was inserted the side of a horizontal conical pipe A, in which the was flowing towards the wider end C, not only none e water escaped through the small tube, but the from a vessel placed at a considerable distance be- vas drawn up through the tube B into the pipe A fig. at p. 126.)

ith these facts before us, we turn with interest to the anatomist too often contemplates with uncon- we mean the different curves in the branching of rteries and veins; for by this law of hydraulics the ion of the branches and trunks of the arteries and ought to be different, as the one vessel, the artery the blood out from the heart, that is, from t h—and the other vessel, the vein, carries it i direction towards the heart, or from bran

in matter of fact, their [illegible]

l characteristic of the vessels. We have heard of anatomy express himself in this manner: .eries are active and powerful vessels, which ırterial blood out from the heart—and they re- :orcible impetus of the heart. When they are the man bleeds to death;—therefore, nature ese vessels into the recesses of the body, taking of every protecting bone—conveying them so ɔnes and the muscles protect them. There are ırities in their course, and their branches go off mined angle, and never irregularly; but the would continue, "are vessels of less import- y convey the blood back to the heart, with a otion, and if they are wounded the blood flows minished a force that you can stop it with the f your finger; accordingly, nature is more neg- hem, they run in all their courses irregularly—), some superficially; and their branches join cs with awkward irregular curves and elbows."

1

2

in good feeling, and is in part true; but it omewhat of the error which runs through most anatomical discourses, of supposing things are irregular, as if the objects in view were inartificially and imperfectly attained. From inattention to the hydraulic principle, he seemed not to have considered that the connection of trunk and branch must vary according to the direction of the stream,—that the direction of the branch, which is adapted to lead the stream from the trunk into the branch, must be altered when the design is to convey the fluid from the branch into the trunk.

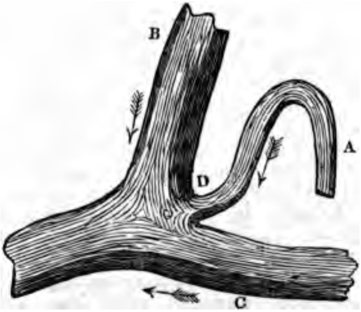
The reader will now understand, that the branch of the artery (No. 1, p. 247) gently diverges from the direction of the stream, while the branch of the vein, in No. 2, enters abruptly and at right angles. We may illustrate this by observing, that if we could suppose the vein substituted for the artery, and the artery for the vein—if the vein carried the blood outwards, instead of towards the heart, and the artery conveyed the blood back to the heart, the blood could not run in the circle; it would be retarded, and congestion would take place, somewhere in its course.

We have seen by the demonstration above, that if the veins of the human body were rigid tubes, and if a hole were made in their sides, air might be drawn in, instead of blood flowing out. This is a matter of vital consequence, for if a very little air be blown into the veins of an animal, it dies in an instant, and there is no suffering nor struggle, nor any stage of transition, so immediately does the stillness of death take possession of every part of the frame.

In conversation with Napoleon's celebrated surgeon, Baron Larrey, on the case of a young man wounded in the neck, he said he had no hesitation in declaring the cause of death to be, air drawn in by the veins of the neck, and he quoted instances occurring at the battle of Wagram. These circumstances greatly increase the interest of an experiment made by Dr. Barry, who found that on introducing a tube into the vein of the neck, and placing the other end of the tube in a vessel of water, the water rose during inspiration. The difficulty of explaining this arises from those veins being membranous tubes,

consequently compressible; but in the act of inspira-
not only are the ribs and breast-bone raised, but the
:les of the neck attached to the collar-bone rise from
reins of the neck. By this means, instead of suffer-
the compression of the incumbent parts, the atmo-
ric pressure is taken off the veins; they are brought
ıe condition of rigid tubes; and the principles of hy-
lics explain the rest. Thus the figure given at p. 128
eservoir emptied by a perpendicular tube, into which
aller tube is inserted. The water descending by the
ır tube, will draw the water up through the lesser
, so as to empty the glass in which its lower end is
ersed.

e shall here give an example of the manner in which
trunk of the absorbent system joins the venous sys-
a circumstance which has not escaped the notice of
omists. The absorbing or lymphatic system consists
set of vessels different from arteries and veins, which
be by a sort of capillary attraction at their extremi-
and convey their fluids towards the centre, without
such impulse as the proper blood-vessels receive
. the heart. The stream in the trunk of this vessel
no force to impel it into the stream of blood in the
s; it enters, therefore, in this manner.



is the trunk of this system, called the thoracic duct;

B is the great jugular vein descending from the head, and C the great vein coming from the arm. These veins join at an angle, and the streams from them, in the direction of the arrows, leave a point between them at D, where there is no pressure. If two tubes enter into a larger tube obliquely, and the water be flowing from the lesser tubes into the greater one, and if a hole be bored at the angle of their union, the water will not escape at that hole. Therefore the fluid from the thoracic duct A meets with no impediment at the point D; when entered, we have seen, by a former diagram, how the attraction of the more forcible stream will draw the contiguous fluid after it. By this contrivance, if we may use the word, the fluid in the absorbing system finds access to the red blood, and is carried into the heart.

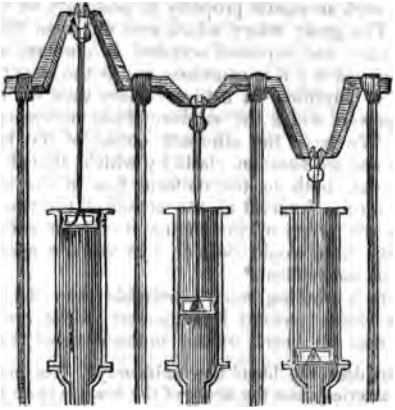
We might continue this subject by considering the influence of respiration on the circulation; but we shall pursue the inquiry into the hydraulic principles, as applicable to the circulation, independently of pneumatics.

The law of inertia, which is of easy comprehension as it regards solids, is also applicable to fluids; it is easier to keep a column of water in a pipe in motion, than to put it into motion from a state of rest.

In a forcing pump, when after each movement of the piston the column of water becomes stationary, power is unnecessarily lost by bringing the column of water, which is in this state of rest, again into motion; but if a second blow of the engine be given to the column of water whilst it is yet moving, it is found to be more easily pressed forward, and no part of the force is lost in urging it from a state of rest into motion. This is evinced in the contrivances of the engineer. He employs two forcing pumps instead of one, and he so applies his lever as to operate alternately on the one and the other; to the end that the water in the pipe may be kept in uninterrupted motion. Let us apply this principle to the circulation of the blood.

If the heart were the only power forcing on the blood, there would be a cessation of motion after each pulse of the heart, and therefore a great part of its power would lost. This explains why there is a power in the ery as well as in the heart. The artery being musar, seconds the operations of the heart; its muscuty, and the muscularity of the heart, are powers exised alternately, and which, acting like the double ke of the engine, permit no interval to the motion of column of blood. If the heart had to act upon a mn of blood at rest, not only much of its force would unnecessarily exhausted, but it would be excited to pel an inert body, and a dangerous shock would arise n the resistance.

f we pursue this subject, and inquire what is essential such a hydraulic machine as we are contemplating, shall perceive that the engineer meets with a diffiy in adjusting the powers of his two pumps, and ls an interval, or pause, in the application of their es.



o obviate this he makes three cylinders, the pistons which are moved by a crank, which so orders the deat of the pistons as to fill up this interval, so that one

s descending; and it and t
nto a common tube, t
the fluid through it.
to look for something
of the circulation.
owever; yet we find a q
hich answers the purp
ehend this, we must observ
e admirable contrivance than
st the action of the other two.
r which, by its elasticity, pre-
pes of two forcing pumps are
B; they convey the water g
air is compressed, and its ela-
that elasticity is exerted withou
the water c, propels it into the

(See figure at p. 132.—)
property is possessed by the arte-
y which goes out from the heart.
ted occasion to observe, makes a
capacious, and is the most perfectly
n nature. Here then we have the
he engineer finds necessary to en-
e alternate action of the heart and
an elasticity which, though passive,
the uniform flow of the blood, by
val in the action of the two powers,
of the engine itself; for without this
uld be such a jar as must speedily de-
sm.*

ng more admirable than the influence
wer; it is greatest in the coats of the
eart, weaker in the coats of that artery

e blood flow uniformly? Not precisely
nce the stroke of the heart is more powerful
ncentrated, than that of the arteries. Durin
of the ventricle of the heart the artery is
is never emptied; and the flow of the blood
course of the circulation is not for an insta

eries c
ened wi
ction, res
ake off all
power, si
celeration
The artery
heart's imp
dilated or enla
stronger impu
action or pass
the artery.
be gradual,
we have
press upon
tion of the
same whilst
solid struct
are led to a
ment of the
ting vess
ice on a

s it recedes from the heart; this very evidentl
use: but we shall take a more sufficient proof,
unhappy one.

As life advances, the arterial system loses m
lasticity, and becomes rigid. This is so comm
currence that we can no more call it a disease
tiffened joints of an old man; it is the forer
the accompaniment of the decline of life.
sometimes takes place too early in life, and t
treme degree; and from its effects we must cal
bid; for it not unfrequently happens that the
power of the heart being still entire and vigo
arteries can no longer sustain it. They are not
dowed with that power which, yielding to th
action, resists, and recoils the more it yield
takes off all sudden shock, and which in yieldin
no power, since on its recoil it gives as much for
acceleration of the blood as was lost of the heart
The artery then becoming rigid, yields indee
heart's impulse, but has no recoil. It is per
dilated or enlarged. It is now called aneuris
stronger impulse from the heart, excited by i
tion or passion, chips and bursts the now ri
the artery. If the breach be sudden, it is
be gradual, a pouch forms—a true aneuris
now we have the proof we require; for this ba
to press upon the solid bones, they are destroye
action of the heart which was so lightly and
borne whilst the vessels were elastic, now beat
a solid structure, in a short time destroys it.
are led to a more accurate knowledge of the fin
ment of the active and resisting properties in t
ting vessels during youth and health, by wh
place on a very slight derangement of those pow

CHAPTER II.

THE ILLUSTRATIONS FROM MECHANICS MAY BE C. TOO FAR. PECULIAR PROPERTIES OF LIFE] BODY. THEY DIFFER IN QUALITY. THEY H. ADJUSTMENT TO EACH OTHER, MORE ADMIRABL THE MECHANICAL CONNEXION.

We are the more desirous of entering upon this : that we may prevent the reader from founding conclusion upon the very mode in which we have l proceeded, that of showing design in every part animal structure by taking our illustrations from t chanism of the body.

When we have admired the connections of the parts, or organs, thus made manifest by comparis machinery, we may go too far, and say, that th rial structure and mechanical relation are to be f still greater minuteness and perfection in the fi tures of the body, proceed to call this organizati erroneously conclude, that out of organization Life. The very term organization misleads ; ye plies something constructed, in which one p operates with another ; but nothing more. Tak body as a whole, there are undoubtedly instances co-operation, but it is in vain to seek the explan life from this ; since life exists in simple and substances, where there is neither construction lation.

Now, although there are mechanical construct relation, as we have seen, in bones, muscles, a dons, the phenomena of the body result from a ence established among the living properties,

ical. The highest medical authorities have seen
:o conclude that life is an endowment, not result-
n organization or construction, but, on the con-
producing it; in other words, that the living
e attracts the new matter, arranges it, and, in
o its continuance and perfection, alters it, and
ı continual revolution in it. For there is nothing
ırious than the uninterrupted and rapid change of
erial of the animal body, from the first pulse of
he last breath that is drawn; of which we shall
ındant proofs before we close this inquiry.

'st approaching the subject we are blinded by
occurrences, and cannot comprehend all the
r which the visible phenomena of the living body
duced. Probably most of our readers believe
to be a necessary consequence of life, and the
:oof of its presence. The peasant stirs up an
with his staff, and if it does not move he is satis-
t it is dead; and such is the experience of man-
We do not reflect that many different qualities of
ng powers must be exercised before sensibility is
.n its visible sign, the motion of the creature. It
ıecessary that the parts shall lock into each other
: cogs of wheels;—the connections established
ı different kind altogether. Each part possesses
rty of life entirely distinct from the other, and
perty of life may exist in the individual part (for
at least) without that co-operation of the whole
s necessary for the motions of the animal.

quality of life is, in one respect, like gravitation
er; that is, when the mass is broken into parts,
vision has its proportion of the endowment, and
separated parts of a living creature possess life.
re the resemblance ceases; gravitation is the
ıality in every part, and uniform in its effects,
he life is exhibited by qualities differing in every
the animal body. Did these parts possess quali-
ıctly similar, they would remain at rest, and
combined, they would not influence each other.

It is the different powers brought into combinatior produce the motion of the whole animal.

If a man fall into the water, and is dragged out tionless, and has ceased to breathe, each part of his may still possess its property of life. Althougl combinations have been destroyed, he may be reviv exciting action in some part of his system. Life remains in brain, and nerves, and heart, and arteric in the muscles, which should enable him to breathe the mutual influence, the bond of their united opera is broken. We may take the analogy of a machine say that the wheels are stopped; but this is in fact different thing; it is the operation of the living ence that is stopped; for we repeat that natur which, of course, is always to be understood the A of Nature) has combined the organs not mechani but by properties of life.

Artificial respiration draws after it the action heart, because the sensibility of the heart is mad spondent to the lungs. Pulsation of the heart, e by the motion of the lungs, is followed by the act the arteries; these organs in operation drive the through the frame, and by the circulation the sus bility of each part to impression, which had been ened, is restored. Action and reaction are re-establi but these actions are not like those of a machine, are living properties; sensibility in one part, co tility in another; and after a variety of these in sensibilities have been for some time in operatio man gives outward token of recovery.

So a person recovering from fainting, after so and irregular breathing, has the respiration renewe succession other parts recover their sensibility an sume their places in the circle of relations; the s capable of being stimulated, and the limbs are ca of motion; the eyelids are opened; by and by the of the eye is sensible to light, and the nerve of t to sound; and, finally, the faculties of the min roused, and its control over the body re-establi

The whole separate endowments of life in the different parts resume their offices;—the last in the train; only the property of the muscle to contract is alone observed by the uninformed, and voluntary motion is the token of entire restoration.

We can imagine a half-learned person to act very foolishly in the attempt to restore the apparently drowned. He has been told that we draw in vital air, and breathe out what is unfit to support life; he imagines that it can be of no use to distend the lungs of the drowning person with his own breath, and precious time is lost. Whereas, the mere distension of the chest, that is, of the lungs, followed by the compression of the chest, and again by the distension, and so on alternately, is the *play of the lungs*, which by sympathy draws the heart into action, and in succession all the vital organs. This is not what chemistry teaches; chemistry shows us that the vital air influences the blood; and it is true that the blood, being refreshed or impregnated with the vital air, renews the properties of life. But this effect on the blood could never take place unless there were some previous consent or sympathy, putting the organs into operation. We repeat that the consent of organs is not the effect of mechanical adaptation, or of chemical action, but of relation established among the vital properties.

If a man be struck by lightning, he has not merely the vital operation of respiration stopped, as in the case of the drowning man, in whom every organ continues to possess its property of life; he is not like a man struck on the head, where one vital organ is so disturbed that the circle of vital actions is broken; in this instance the electric fire passes through every fibre and every organ; all the qualities of life, whether residing in the brain, nerve, or muscle, are instantaneously destroyed; and the moment of death is the commencement of dissolution.

Mr. John Hunter illustrated this somewhat familiarly. If you bruise the head of an eel, its body writhes; but if it be taken by the tail, and struck on the
so that *every part* of its body receives the

all the parts are killed, and it remains motionless.
an animal is killed by that violence which inju
important organ, the property of life remains fo
tain time in every part; those parts have no corr
ence, and there is no outward token of life;
vital principle is still capable of exhibiting on
most important properties; it arrests the oper
those chemical affinities which belong to dead ma

Thus the reader perceives, that, although he b
to comprehend the design or intention manifeste
structure of the body by mechanical instances or
risons, it is when we contemplate the influence
living principle, that we have a higher convictio
Omnipotence which has formed every creatu
every part of each creature, with that appropriate
ment of life which suits it to act its part in the
system.

We must learn to distinguish between the deat
animal and the death of the parts of the animal—
apparent death and dissolution, or the separation
quality which distinguishes living matter.

Viewing the subject generally, as Mr. Hunt
there are not two kinds of matter, but two condi
matter. It is at one moment forming beautiful
ations, as in the flower, through the principle of li
at another, it is cast away as noxious, undergoing
by decomposition, from chemical processes solel
want of combination in the whole animal body
apparent death. The loss of life in all the par
animal body is absolute death, and the material
subjected to the influence of the chemical affinitie
of being urged into motion by life.

The jackstone produces motion in one part o
chine; that, varied by mechanical influence, is
nicated to a second; from the teeth of one wh
communicated to the corresponding leaves of the
and from the pinions to the fusees. But wha
notion it is to suppose that the mere property o
in the jackstone is like the influence of life!

The weight is the power, in the language of cians; but it does not reside in the parts of a machine, nor does it exhibit different qualifications in these parts. Separate them, and they are nothing. On the contrary, no one part of an animal body is in this manner dependent on another for its property of life. The property is inherent in the part itself, and the wonderful thing is that each property in the several organs corresponds with the others, so as to form a circle of vital operations. There is no transmission of power, in all this, from part to part—no train of connection to be traced as from the jack-stone, or the spring, along the parts of the machine. There is, therefore, in truth, no resemblance between machinery and the influences in operation in a living body. What is to be admired in a living body is not merely the adaptation of bones, muscles, and tendons, forming a mechanical apparatus, but rather the different qualities which life bestows upon different parts; these qualities put the parts into relation each according to its place in the circle of the economy; and among innumerable properties of life in the individual parts, produce that perfect co-operation as if one principle only actuated the whole.

When a person moves under the direction of the will, nothing can be more simple to our understanding, because we do not attempt to trace the links, far less to estimate the powers in the several parts influenced during this familiar action. But if there be the slightest diminution of sensibility of one nerve so that it shall not transmit sensation; or if there be any disturbance which retards in the least degree the transmission of the will along another appropriate nerve; if the muscle be benumbed, or have lost its irritability; if the action of the blood-vessels has been either diminished or increased beyond their ordinary course, either in the organs of sense, the brain, or nerves; we are appalled by the consequences. The impressions of things are not felt; the senses are unexercised; the limbs remain inactive; one half, or the whole, of the body is a load, as if there were a living being in a dead body—a body whose parts refuse their office, appearing dead, though they are not so. The correspondence of their living qualities has alone been disturbed, the movement which results from the whole is stopped, and there is apparent death.

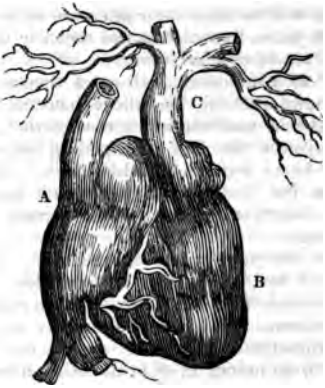
What confusion then must be engendered in the minds of those who would confound the phenomena of life, as presented in the entire framework of the body, with those separate qualities of life which, residing in the several parts, must enter into combination for the motion of the whole! The next step of this unphilosophical manner of treating the subject, is to make the organization the source of the living property,—as if any combination of organs could produce life,—as if those organs could have motion without the distinct endowments of life in their separate parts,—as if they co-operated mechanically, and not from the correspondence among their living properties. Those who thus reason mean to say that parts are made so finely as to move of themselves, one part propelling another, and the motion of the whole producing life. It is quite clear that this confusion of ideas arises from contemplating the phenomena of the perfect animal, in which all intermediate influences are confounded. On the other hand we present this proposition.

The several *simple* substances of a living body have each an endowment of life bestowed upon them. Let us take the obvious qualities, of sensibility—the power of transmission — and the power of motion; each of which is appropriate to a particular substance. When these qualities are put in relation, impressions may produce motion, and thus there are three distinct properties of life brought into operation. Where is the organization or construction here? Without those living endowments these parts would be inoperative, in whatever juxtaposition placed. The mechanical construction of the body is one thing: and we are able to admire it, because it can be illustrated by comparison with our own contrivances; the combination of living properties is another and an entirely different thing.

We here reach the limit of philosophical inquiry. Hitherto all has been flattering to the pride of the creature; but we must now humbly acknowledge the inscrutays of the Creator; and ceasing to trace the origin , more than we do that of gravitation, we should cupied in observing its laws, not in exploring its .

shall take an instance to illustrate the difference xt the mechanical connection of parts and their ns through the living properties; and it will, at me time, show how curiously the living properties e mechanical properties are made to correspond ach other.

stream of water is converted into a mechanical ; it fills a cistern, which is attached to a lever; istern descends by the weight of water; by its nt a valve is pushed open; the water escapes, and stern ascends, and remains so, till the stream flowto it again, depresses it. Thus the regularity of pply of water gives regularity of motion to the ne. Compare this with the heart.



e may describe the heart as consisting of two cavithe one called the *Auricle*, and the other the *Ven-* . The sinus A receives the blood returning by

tension produces action, and the propulsion
from the cavity allows a momentary state
another volume of the blood excites anothe

But we have now to observe, that when t
or muscular power was bestowed upon the
directed by a law entirely different from th
as possessed by other muscles. A propert
activity and rest was given to it, quite un
tractility of other parts; and accordingly w
is empty, when there is no distension of bl
two cavities will continue their alternate act
the heart be taken from the animal recently
continue to act in regular successive pulses,
cavity, and then the other, and so on succ
long time, until the life be quite exhauste
cavities will thus continue in alternate actio
were employed in the office of propelling th
there is no blood contained within them.
fluous to observe, that no such thing could
case of the cistern and lever, were the strea
cease running.

Thus we distinguish two things quite
mechanical or hydraulic provision, by whic
cisterns, the auricle and ventricle, shall be
plied, and alternately filled and emptied—
perty of contraction in the heart; not a mer

y through a long life. The living property of
t exhibits a variety adapted to its office, and a
ndence still more admirable than the mechanical

e thus particular in distinguishing the mecha-
aptation of parts from the co-operation of the
luences residing in the several parts; for there
who will take the illustration from mechanics,
their inquiry there, and who entertain a con-
tion of the dependence of the life of the body on
anism.

er mistake, which some philosophical inquirers
, is to fancy that the principle of life is of a
nature. There is indeed an unwillingness in
cknowledge that their powers of reason are ex-
and that they have arrived at an ultimate stage;
ld fain set up some contrivance to hide the hu-
truth. Whatever notions have prevailed in the
t different epochs, of heat, electricity, or gal-
we find an attempt to explain the phenomena of
n application of the powers, with which they
n successful in their physical inquiries. Expe-
without reason are equally delusive with hypo-
those who will not give themselves the labour
ht, desire to witness striking phenomena; won-
k, they believe that they are engaged in expe-
investigation, when their state of mind is little
an idle amazement. A calf's head is made to
a man cut down from the gallows to move like
of cards pulled with strings; the jaws move, and
roll, and this is done by conveying the galvanic
the nerves; here it is supposed that nothing less
principle of life itself can work such wonders,
galvanism is this principle.

g aside the circumstance already stated, of life
g totally different phenomena in union with dif-
rts, is there any point of resemblance between
n and life? Does tying the nerve stop the in-
of galvanism, as it does the influence of life?
lvanism course along a cord when it is surrounded

buted to its being a high stimulus conveye
moist animal body, and exciting the powers
insulated in the several parts; and in
forces, far from renewing them, it exhau
gether.

The uses made of galvanism in the exp
living phenomena, should make sensible me
how they carry the legitimate induction
science into another department. They w
to call the irritability or contractility o
endowment of life, but seek to explain it b
They employ the microscope; they fin
fibre to be some thousandth part of an inc
they see plicæ or folds; they imagine t
into which the fibres are divided; they
cells with two different gases, and explode
galvanic influence of the nerves; and th
dilating the cells in one direction, causes
in another. This is the theory of muscul
period of the discovery of the gases; and
hypothesis, supposed applicable to the la
companies every considerable improvemen

In the most modern and the most popul
on Physiology, by Mons. Richerand, he
appears to me by much the most ingenio
which carries with it the greatest proba

'it is also necessary to suppose, that a nervous
lirected through the muscle to determine the
sition, as the electric spark forms water out of
s."

is the chemical theory of muscular motion; it
n entire misunderstanding of the phenomena of
motion, and of the beautiful provision in every
or its appropriate office. The muscles, which
rvient to the organs of sense, differ in their
s altogether from the voluntary muscles of the
The hollow muscles, as they are termed, those
rry down the food, and which carry round the
circulation, vary in their time and manner of
cording to their offices; but what conception
ve of such adjustment of powers, who is enter-
imself with a theory, that supposes a sudden
to take place in the fibres of the muscle at their
tion? Inductive reasoning, which has carried
e highest acquirements in physical science, is
aside; conjectures totally inconsistent with the
a of life are employed in its stead; and the
ilosopher becomes a very indifferent physio-

CHAPTER III.

OF SENSIBILITY.

UNDER this head are comprehended, not any se
or feeling of the mind, but the sensations of the
We form our notions of sensibility from that
skin; and it is no doubt necessary that we shoul
It is in constant communication with things aro
and affected by their qualities; it affords us infor
which corrects the notions received from the other
of sense, and it excites our attention to prese
bodies from injury. We are so familiar with the
effects of injuries upon the surface, that there is
who does not imagine that the deeper the inju
more dreadful the pain. But, on the contrary,
well-established fact, that to such irritants as wou
the skin pain, the internal parts are totally ins
And it is equally certain, that though the nerves,
struments of sensation, are incapable of produci
perception without the brain, yet the brain itself, t
which is the seat of intellect, and to which every i
sion must be referred before we become conscious
is itself as insensible as leather. These consid
show us that sensibility to pain is not a necessary
of life, and they naturally lead to the inquiry fo
purpose is sensibility bestowed, and how is it dist
in the body?

We have first to show that the skin has sensi
exactly suited to the functions it has to perform.
no doubt informs us, that warmth and cold are on
tive degrees of heat; to the skin they are distinc
tions, and excite in different ways both the mind
bodily functions. Cold braces and animates to e
whilst the warmth which is pleasant to us, is gen

›erations of the animal economy. Their alternations he most constant sources of our enjoyment, and at ıme time conduce to exertion and to health. All however, belongs to the skin exclusively; parts ıal, although peculiarly sensible to their proper lus, give no indication of sensibility to heat; if there :ernal sensations of heat, they are morbid and decep-

Molten lead would produce pain and death being d into the interior of the body, but the sensation of ng is a property of the surface only. It is the ex- ıf that particular sensation, which is calculated, like :her endowments of the skin, to suit the medium in ı we live, and to force us to the regulation of the ›rature necessary to preserve life.

ıch, or the sensibility to bodies pressed upon the is likewise a distinct and appropriate sense. The ›ility of the skin to pricking, cutting, or tearing, is ı curious contrast with the sensibility of the solid al textures, as bone, cartilage, and ligament. We ırrived at the full comprehension of this subject very ·. Disagreeable experiments have been made, but llowing is as interesting as it was innocently per- d. A man who had his finger torn off, so as to by the tendon only, came to a pupil of Dr. Hunter. all now see," said the surgeon, "whether this man ıy sensibility in his tendon." He laid a cord along ıger, and, blindfolding the patient, cut across the ı. "Tell me," he asked, "what I have cut ?" "Why, you have cut across the cord, to be was the answer. By such experiments it became nanifest, that bone, gristle, and ligament, were in- le to pricking, cutting, and burning. Were they, ore, insensible? The reader will answer—Surely, matter proved. But before we finally decide, let e this into consideration,—that the sensibilities of dy differ in kind as well as in degree; and every ıas its peculiar kind, as well as its degree; and part has its kind of sensibility with reference to its ›n, and also with reference to its protection from ›e. If the membranes between the bones of our great joints, or the cords which knit the bones, we sible in the same manner and degree with the sk should be incapable of motion, and screwed to our as the man appears to be who has a violent att acute rheumatism.

But although these bones and cartilages, or g and ligaments, be not sensible as the skin, or the of the eye, they possess that which is suited t condition, which permits their free use, and yet that too free exercise which would be injurious t textures, or raise inflammation in them. The lig and tendons, then, which are insensible to prickin ting, and burning, are sensible, nevertheless, to s ing and tearing! It is remarkable that such men Hunter and Haller, the luminaries of their s should have held the opinion that the bone and the brane which covers it (the *periosteum*), the gris cartilages, the ligaments of joints, and the tend muscles were insensible parts, and yet be in daily ance on those who suffer the pain of a sprained where there are no parts to suffer but those enum and where the pain, excessive in degree, was felt instant of the sprain. These considerations explai that pain is the safeguard of the body. This capa conveying painful impressions to the mind is not giv perfluously to all parts; on the contrary the safe e and the enjoyment of every part is permitted w alloy, and only the excess restrained.

This subject is finely illustrated by the apparent sibility of the heart. The observation of the adn Harvey, the discoverer of the circulation of the bl to this effect. A noble youth of the family of gomery, from a fall and consequent abscess on th of the chest, had the interior marvellously expo that after his cure, on his return from his trav heart and lungs were still visible and could be ha which when it was communicated to Charles I., pressed a desire that Harvey should be permitted the youth and examine his heart. "When," say vey, "I had paid my respects to this young nob

onveyed to him the king's request, he made no con-
ent, but exposed the left side of his breast, when I
cavity into which I could introduce my fingers and
b; astonished with the novelty, again and again I
red the wound, and first marvelling at the extra-
ary nature of the cure, I set about the examination
e heart. Taking it in one hand and placing the
r of the other on the pulse at the wrist, I satisfied
lf that it was indeed the heart which I grasped. I
brought him to the king, that he might behold and
so extraordinary a thing, and that he might perceive,
did, that unless when we touched the outer skin, or
he saw our fingers in the cavity, this young noble-
knew not that we touched the heart!" Other ob-
tions confirm this great authority, and the heart is
red insensible. And yet the opinions of mankind
not be lightly condemned. Not only does every
ion of the mind affect the heart, but every change
e condition of the body is attended with a corre-
ding change in the heart: motion during health—
nfluence of disease—every passing thought—will in-
ce it. Here is the distinction manifested. The sen-
ty of the skin is for a purpose, and so is the sensi-
of the heart. Whilst the skin informs us of the
ties of the external world and guards us against in-
from without, the heart, insensible to touch, is yet
to every variation in the constitutional powers, and
ct to change from every internal influence.

ere is in the several organs of the body, as it were,
tinct life; that is, they possess sensibility, the grand
wment of life, necessary to their condition and
ted to their appropriate stimulus. The impressions
upon them will sometimes rouse them into activity,
ll muscles into action which are necessary to their
ions or for their protection; and this oftentimes
out reference to the mind at all, and consequently
out our consciousness.

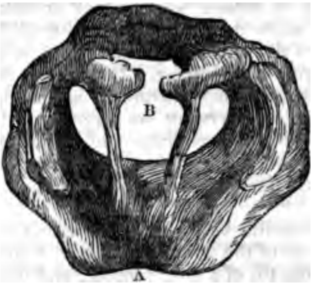
rhaps we have the most agreeable example of this
e eye. That organ has been selected, in the Pre-
ary Discourse of the Objects and Pleasures of

Science, as showing how mechanical advantage
in the arrangement of the muscles to produce vel
movement in guarding the eye. But this fine me
would be lost if the excitement depended on ou
if there were not a sensibility appropriate to the
and an influence quicker than thought. It is not
ing the pain of the offensive body, or by estim
dangers and acting on the conviction, that we c
eye to avoid injuries. This would be an operatio
slow for the intended purpose; and therefore the
possessing these extraordinary provisions, are put
tion with a sensibility more admirable still. So
light foreign body touches the eyelashes, they giv
and cause a motion both of the eyelids and eyeball
than thought. The eyelashes, seated on the ter
tremities of sensitive nerves, preserve the eye
ways—by guarding its interior from the lateral lig
by exciting the motion of the eyelids, even bef
offensive body can touch the eye's surface.

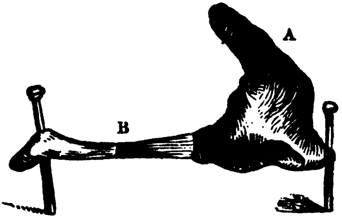
We may take another illustration to show how
lity, one of the endowments of the living part, is
to the mechanical organization, and with an appro
more admirable than the mechanism. When w
of the sensibility of the skin, it is still possible to
ceive its nature, and to suppose it accident merel
in the instance to be adduced, the sensibility is di
and it is put in connection with a hundred muscles
out this high and peculiar sensibility, and its mul
relations to muscles, independent of volition, th
chanism we are about to describe would be quite us

The top of the windpipe is called the *larynx*, an
sists of five elastic cartilages. These do not merely
the sides of the windpipe apart, and the passage f
breath free, but they perform offices important t
economy both of body and mind; they are an essenti
of the instrument of voice; they, at the same time,
the lungs from injury.

The *thyroid* cartilage is the largest of the cartila
the larynx; it is that we feel projecting on the for
of the throat called the *pomum adami*, (A.) It is



on to the fine apparatus behind it, and indeed this is
reason of its name, (*scutiform*, like a shield.) Within
thyroid stand the *arytænoid* cartilages, (B.) This
ilage is of an irregular triangular form. It is socketed
rticulated on the cartilage below, and is perfectly
able. To the corner which projects forwards the



ment (B) is fixed, and to its other sides five little
cles are attached ; these muscles, by moving the car-
ge, draw and vary the position of the ligament. It is
e cartilages and this ligament, which, vibrating in the
m of air, give the tremor, and vocalize the breath ;
tones so produced are articulated in speech.

his is a subject far from being exhausted in our phi-
phical works, and may call for observation after-

wards; but at present we may look on these liga
not as the *cordæ vocales*, but in another of their o
forming the slit which opens and shuts in breathi
the protection of the lungs. But here it is perti
remark, that in the structure of an animal bo
organ is made subservient to several functions,
interference in the performance of any of them.
especially true of the larynx. It is one of the
only, and the least important, that we have at pr
observe.

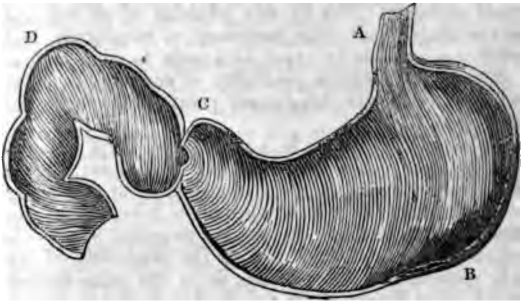
The ligaments being invested with the linin
or membrane of the wind-pipe, draw it into the
a slit like the till of a shop counter, and this is th
of the glottis, (*rima glottidis.*) This slit opens an
with every inspiration, moving as we see the nos
in breathing. But the most admirable thing of a
acute sensibility given to this part, and to no o
that the lightest husk, or seed, or smallest fly, d
with the breath, and touching the margin of the
is caught there by the rapid action of the musc
consequent closing of the aperture. Now were t
vision for the protection of the lungs to be only t
perfect, there would be an effectual means of pre
the intrusion of foreign matter into the delicate
the lungs, but not for its expulsion from the c
which it had reached. Accordingly, although t
sibility of the glottis is put in operation with the s
of the chink, it also animates another class of m
viz. all those which, seated on the chest, com
and force out the air in coughing; and these co
in one powerful and simultaneous effort, whilst th
is closed, overcome that constriction, and pro
breath through the contracted pipe with an e
force, which brushes off the offending body.
one thing more, necessary to this most important
familiar action;—the lungs are never empty of
breathing we do not fully expel the air; if we di
would be a period of danger occurring sevente
in a minute; for in the first part of each ins
something might be drawn into the wind-pipe

would suffocate. But by this provision of air retained in the lungs more than necessary to respiration, and which it is possible to expel by a more forcible expiration, there is always a possibility of coughing and expelling the offensive thing at any point of time in the act of inspiration.

The sensibility seated in a spot of the throat so beneficently, does not extend into the wind-pipe; for we cannot more admire the perfect adaptation of this living property, than the circumstance of its never being bestowed in a superfluous degree, nor extended where it is not absolutely required. Just as the sensibility of the skin protects the parts beneath, so in the same manner does the sensibility of the top of the wind-pipe protect all the interior of the tube, and the lungs themselves, without the necessity of this property of irritability extending through the whole continuous surface.

The simple act of sneezing affords a very curious instance of the mutual adaptation of muscular activity and the governing sensibility. The sensation which gives rise to this convulsive act is seated in the membrane of the interior of the nostrils, and we are not surprised with the difference of sensation from that in the throat which excites coughing. But is it not a very curious thing to find some twenty muscles thrown out of the action excited by irritation of the nose; and as many excited which were not in the class of those influenced in coughing; and for the very obvious purpose of shutting the passage by the mouth, or at least forcibly driving the air through the nostrils? No act of the will could so successfully propel the air through the nose in such a way as to remove the offensive and irritating particles from the membrane of the nose, and clear those passages.

These last examples of an appropriate sensibility might introduce us to an acquaintance with those internal sensibilities which govern the actions of parts quite removed from the influence of the will; but the description of them may be deemed unnecessary. We shall just hint at the guard which nature has placed on the lower orifice of the stomach, to check the passage which the appetites



of hunger and thirst may have given at the upper orifice (A) to aliments not easy of digestion. This lower orifice (C) is encircled with a muscular ring; the ring is in the keeping of a watchful guard. If we are employing the language of metaphor, it is of ancient use. The Greeks called this orifice *pylorus*, which signifies a porter,* and his office is this.—When the stomach has received the food, it lies towards the left extremity, or is slightly agitated there. When the digestive process is accomplished, the stomach urges the food towards the lower orifice. If the matter be bland and natural it passes, and no sensation is experienced. But if crude and undigested matter be presented, opposition is offered to its passage, and a contention is begun which happily terminates in the food being thrown again to the left extremity of the stomach, to be submitted to a more perfect operation of the digestive powers seated there. It is during this unnatural retrograde movement of the food, that men are made sensible of having a stomach. Yet the sensations, how unpleasant soever, are not to be regarded as a punishment, but rather as a call on reason to aid the instinctive powers, and to guard against disease, by preventing impure matter from being admitted into the rtion of the intestinal canal, which absorbs, and would us carry those impurities into the blood to engender sease.

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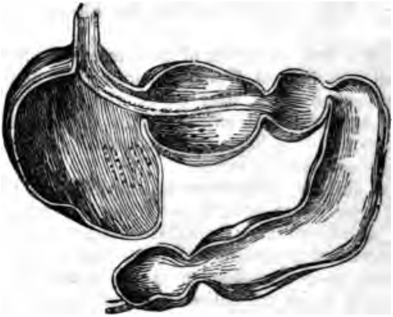
* The upper orifice was called by them *œsophagus*, as it were *the purveyor*, from two words signifying to bring food.

Such are a few examples of the variety in the sensi- lities of the animal frame; guarding us against ex- rnal influences when they would threaten destruction the framework, and adjusting the operations of in- rnal parts too complicated and too remotely situated for e superintendence of reason.

Medical authors, without being empirics, do, notwith- anding, take great advantage of our ignorance. We n all of us take warning from the sensations experienced the process of digestion, and there can be no harm in iving every man a confidence in the sensibility of his omach, and in its indications of healthy or disturbed nctions. We have the best proof of what we wish to culcate in the action of the ruminating stomach. A w swallows the gross herbage, and fills its large first mach. When it chews the cud, the stomach, by its tion, rolls up the grass into distinct pellets, or balls, th as much regard to the office of its being rejected o the mouth as we do in masticating for swallowing. hen the ball is brought into the mouth and chewed, is again swallowed; but in descending into the lower t of the gullet a muscle draws close the aperture by ich it passed into the large stomach in the first in- nce, and it is now ushered into a second stomach, and successively onwards to that stomach in which the estion is performed. The curious muscular apparatus which this is accomplished needs not be described; t surely the sensibility which directs it, which, kept rt altogether from the will, is yet, in its results, so e the operations of reason, presents a subject of just niration.

The elastic structure of the camel's foot; the provi- n around its eyes for ridding them of offensive par- les; the power of closing its nostrils against the clouds sand; and its endurance of fatigue—would not enable to pass the desert, unless there were provisions for the lgment of water in its stomach, and unless this appa- us were animated by peculiar sensibilities; for there



are muscles to retain the fluid in the cells of its stomach, only permitting it to ooze out according to the necessities of the animal; and there is a muscle, represented in the figure above, which pulls up the one or the other of the orifices of the different stomachs to receive the food from the lower end of the gullet, according to its condition, whether to be deposited merely as in a store, or to be submitted to the operation of digestion.

The surprising thing in all this, is not so much the mechanical provision as the governing sensibility. What, for example, should in the first place impel the grosser food, when collected, into the first stomach? What should, in the next place, and after rumination and mastication in the mouth, carry it into the third stomach; since water is carried into neither of these, but into the cells of the second stomach?

Yet, after all, this only brings us back to a sense of the operations of our own bodies. The act of swallowing, the propulsion of the food into the gullet, and the temporary closing of the windpipe at such a time, is just as surprising. This latter operation is never deranged but by the interference of the will. If the individual attempts to speak, that is, to govern these parts by the will, when they should be left to these instinctive operations; or if terror, or some such mental excitement, prevail at the moment of swallowing, then the morsel may stick in the throat.

All this shows how perfect the operations of nature are, and how well it is provided that the vital motions should be withdrawn from the control of reason, and even of volition, and subjected to a more uniform and certain law.

But the point to which we would carry the reader is this, that though there are the proper sensibilities of the body, with reference to perception or consciousness, yet there are others no less curious, which control the internal operations of the economy; and that the mechanical provisions are but a type of what is promised to him who will look into the sensibilities of the body for the proof of power and contrivance.

Now the human stomach, though not so complicated in its apparatus of macerating and digesting vats, is possessed of a no less wonderful degree of governing sensibility, which may be trusted as surely as the most skilful physiologist.

We are told that we must not drink at meals, lest the fluid interfere with the operation of digestion; of this there need be no apprehension. The stomach separates, and lets off with the most curious skill, all superfluous fluid through its orifice, while it retains the matter fit for digestion. It retains it in its left extremity, permitting the fluid to pass into the intestines, there to supply the other wants of the system no less important than the digestion. The veterinary professor Coleman ascertained that a pail of water passed through the stomach and intestines of a horse, at the rate of ten feet in the minute, until it reached the cæcum. Drinking at a stated period after meals, say an hour, is at variance with both appetite and reason. The digestion is then effectually interfered with; for what was solid has become a fluid, (the *chyme.*) This fluid is already in part assimilated; it has undergone the first of those changes which fit it ultimately to be the living blood; and the drink mixing with this chyme in the inferior extremity of the stomach, or first intestine, must produce disturbance, and interrupt the work of assimilation.

Looking in this manner upon the very extraordinary properties of the stomach, we perceive how natural it was for physicians to give a name to the sensibility of which we have been speaking. The *Archeus* of Van Helmont, the *Anima* of Stahl, were the terms used to designate this nature, principle, or faculty, subordinate to, and distinct from perception;—a notion entertained, and more or less distinctly hinted at, by philosophers from Pythagoras to John Hunter.

A modern philosopher,* of whom, in this instance, it would be difficult to say whether he be serious or playful, with some plausibility, however, asserts that it might be possible to carry on the business of life without pain. If animals can be free from it an hour, they might enjoy a perpetual exemption from it. Animals might be constantly in a state of enjoyment; instead of pain, they might feel a diminution of pleasure, and might thus be prompted to seek that which is necessary to their existence.

In the lower creatures, governed by instinct, there may be, for aught we know, some such condition of existence. But the complexity and delicacy of the human frame is necessary for sustaining those powers or attributes which are in correspondence with superior intelligence; since they are not in relation to the mind alone, but intermediate between it and the external material world. Grant that vision is necessary to the developement of thought, the organ of it must be formed with relation to light. Speech, so necessary to the development of the reasoning faculties, implies a complex and exceedingly delicate organ, to play on the atmosphere around us. It is not to the mind that the various organizations are wanted, but to its condition in relation to a material world.

The necessity of this delicate structure being admitted, it must be preserved by the modifications of sensibility, which shall either instinctively protect the parts, or rouse us into powerful and instantaneous activity. Could the eye guard itself, unless it possessed sensibility greater than the skin? Could it guard itself, unless this sensibility were in consent with an apparatus which acted as quick as thought? Could we, by the mere influence of pleasure, or by any cessation or variation of pleasurable feelings, be made alive to those injuries which might reach the lungs by substances being carried in with the air we breathe? Is there anything but the sense which gives rise to the apprehension of suffocation, that would produce the instant and sudden effort which could guard the throat from the intrusion of what was offensive or injurious? Pleasure is at the best a poor motive to exertion, and rather induces to languor and indulgence, and at length indifference. To say that animals might be continually in a state of enjoyment, and that when urged by the necessities of nature, such as thirst, hunger, and weariness, they might only feel a diminution of pleasure, is not only to alter man's nature, but external nature also; for, whilst there are earth, rocks, woods, and water for our theatre of existence, the textures of our bodies must be exposed to injuries, from which they can only be protected by a sensibility adapted to each part, and capable of rousing us to the most animated exertions. Take away pain, and take also away the material world, by which we are continually threatened with injury; and what, after all, is this, but imagining a future state of existence, instead of that in which mind and matter are combined? If all were smooth in our path, if there were neither rugged places nor accidental opposition, whence should we derive those affections of our minds which we call enterprise, fortitude, and patience?

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* Hume.

Independent of pain, which protects us more powerfully than a shield, there is inherent in us, and for a similar purpose, an innate horror of death. "And what thinkest thou (said Socrates to Aristodemus) of this continual love of life, this dread of dissolution, which takes possession of us from the moment that we are conscious of existence?" "I think of it, (answered he,) as the means employed by the same great and wise artist, deliberately determined to preserve what he has made."

The reader will no doubt here observe the distinction. We have experience of pain from injuries, and learn to avoid them; but we can have no experience of death, and therefore the Author of our being has implanted in us an innate horror at dissolution; and we may see this principle extended through the whole of animated nature. Where it is possible to be taught by experience, we are left to profit by it; but where we can have none, feelings are engendered without it. And this is all that was necessary to show how the life is guarded; sometimes by mechanical strength, as in the skull; sometimes by acute sensation, as in the skin and in the eye; sometimes by innate affections of the mind, as in the horror of death, which will prevail as the voice of nature, when we can no longer profit by experience.

But the highest proof of benevolence is this, that we have the chiefest source of happiness in ourselves. Every creature has pleasure in the mere exercise of his body, as well as in the languor and repose that follow exertion; but these conditions are so balanced that we are impelled to change, and every change is an additional source of enjoyment. What is apparent in the body, is true of the mind also. The great source of happiness is to be found in the exercise of talents, and perhaps the greatest of all is when the ingenuity of the mind is exercised in the dexterous employment of the hands. Idle men do not know what is meant here; but Nature has implanted in us this stimulus to exertion, that she has given to the ingenious artist—the man who invents, and with his hands creates, a source of delight, perhaps greater, certainly more uninterrupted, than belongs to the possession of higher intellectual powers, and far beyond any that falls to the lot of the minion of fortune.

We believe that every thinking person may have *wherewithal* in his own sphere to tutor him, and bring *him to* the temper of mind and belief which we would

. Yet there is something peculiarly appropriate
udy of our own bodies. In chemistry we are so
e agents as to forget the law, and the law itself
least to intermit. But in the changes wrought
nimal frame, the directing power is uniform in
nce, and holds all in harmony of action.

ow learn without difficulty and without mystery,
meant by organic and animal sensibility. The
hat condition of the living organ which makes
le of an impression, on which it reacts and per-
functions. It appears from what has preceded,
sensibility may cause the blowing of a flower, or
on of a heart. The animal sensibility is indeed
oper term, because it would seem to imply that
site, organic sensibility, was not also animal;
neans that impression which is referred to the
m; where (when action is excited) perception
effort of the will are intermediate agents between
ation and the action or motion.

nay sum up the inquiry into sensibility and mo-
s:—

ne peculiar distinction of a living animal is, that
te particles are undergoing a continual change or
on under the influence of life. Philosophers
plied no term to these motions.

n organ possessed of an appropriate muscular
and of sensibility in accordance with the moving
nt, as the heart, or the stomach, has the power
n without reference to the mind. The term
ic, sometimes given to those motions, conveys a
dea of the source of motion, as if, instead of being
power, it were consequent upon some elastic or
ical property.

nere are sensibilities bestowed on certain organs,
lding a control over a number of muscles, which
them in action in a manner greatly resembling
ence of the mind upon the body, yet indepen-
the mind; as the sensibility which combines the
in breathing.

the last *instance* a large class of muscles were mbined without volition. But the whole animal fabric ay be so employed; as in the instinctive operations of imals, where there is an impulse to certain actions not companied by intelligence.

5. A motive must exist before there are voluntary acions, and hence philosophers have supposed that there an be nothing but instinctive actions in a new-born child. But we must distinguish here what are perfect at first, and what are imperfect and irregular, and become perfect by use and the direction of the will. The act of swallowing is perfect from the beginning. The motions of the legs and arms, and the sounds of the voice, are irregular and weak, and imperfectly directed. It is the latter which improve with the mind. From not knowing the internal structure, and the arrangement of the nerves, philosophers, as Hartley, supposed that an instinctive motion, such as swallowing, may become a voluntary act. Volition in the act of swallowing consists merely in putting the morsel within the instinctive grasp of the fauces, when a series of involuntary actions commence, over which we have no more control in mature age than in the earliest infancy. Swallowing is not a voluntary action, and the thrusting the morsel back with the tongue is like putting the cup to the lip. It is the preparatio for the act of swallowing that is voluntary, but over th act itself we have no control.

It is an error to suppose that all muscular actions ar in the first instance, involuntary, and that over some them we acquire a voluntary power. The power of lition over the muscles of the body is provided for appropriate nerves, and no apparatus which is not s plied with that particular class of nerves can ever any exercise or study, become subject to volition. child's face has a great deal of motion in it, very di ing from its resemblance to expression, before ther be any real motive to the action. It will crow make strange sounds, before there is an attempt at s But this gradual development of intelligence and sition of power ought not to be called the will att influence over involuntary muscles; since, in fa apparatus of nerves and muscles is prepared and waits for the direction of the mind with so perfect a readiness, as to fall into action and just combination before that condition or affection of the mind which should precede the action takes place. A child smiles before anything incongruous can enter the mind, before even pleasure can be supposed a condition of the mind. Indeed, the smile on an infant's face is first perceived in sleep.

6. All the motions enumerated above are spontaneous motions belonging to the internal economy; but the external relations of the animal, the necessity of escaping from injury, or warding off violence, require a sensibility suited to those outward impressions, and an activity consequent on volition. Nothing less than perceptions of the mind, and voluntary acts, suited to a thousand circumstances of relation, could preserve the higher classes of animals, and man above all others, from destruction.

All these provisions proceed from an arrangement of nerves and muscles. The mechanical adjustment of the muscles and tendons is perfect according to the principles of mechanics. The muscles themselves possess a different property; they are irritable parts; motion originates in them. This living property of contraction is admirably suited, in each particular muscle, to the office it has to perform. In some it is suitable that the muscles should act as rapidly as the bowstring on the arrow; in others the action is slow and regular; in others it is irregular, and after long intervals, according as the functions to which they are subservient require. The motions of the limbs, the motions of the eye, those of the heart and arteries, stomach and bowels, are all different. This appropriation of action is not in the muscles themselves, but as they stand in relation to the nervous system, and the sensibilities which impel them.

We hope, then, by the course we have taken, that we have carried the reader to a higher sense of the perfection of the animal structure. We first drew him to observe provisions in the strengthening of the
adjustment of their extremities to the joints,
of the tendons, and other such mechanical

proving to him the existence of intention in the formation of the solid fabric of the body. We have then explained how that motion is produced which was at all times familiar to him, but even the immediate causes of which he did not comprehend. We have, in the last place, shown him that under the term life he has a still more admirable subject of contemplation in the adjustment of those living properties; in the sensibilities differing not so much in degree as in kind; and in their appropriation, both to the operations of the internal economy, and to the relations external, and necessary to safety.

It is not possible to contemplate these things without having the full proof before us of the power of the Creator in forming and sustaining the animal body. As a man with *gutta serena* may turn his eyes to the sun, and feel no influence of light; so may the understanding be blind to these proofs; and we may say, with the celebrated Dr. Hunter, that he who can contemplate them without enthusiasm, must labour under a dead palsy in some part of his mind, and we must pity him as unfortunate.

CHAPTER IV.

THE CHANGES IN THE MATERIAL OF THE ANIMAL BODY DURING LIFE.

have seen the motions performed in the animal body ugh the actions of the muscles and the play of the hanical parts, and we have had occasion to reflect he action of the heart and the motion of the blood he circulation; but these are as nothing compared ı the interest of our present subject—the changes ıg forward in the solid material of the frame. Is it surprising that the individual who retains every pe- ırity of body and of mind, whose features, whose gait mode of action, whose voice, gestures, and com- :ion we are ready to attest as the very proof of per- ılity, should in the course of a few days change every icle of his solid fabric?—that he whom we suppose saw, is, as far as his body is concerned, a perfectly ›rent person from him we now see? That the fluids change we are ready to allow, but that the solids are ; ever shifting seems at first improbable. And yet, ıere be any thing firmly established in physiology, if ·e be truth in the science at all, this fact is incontro- ible.

'here is nothing like this in inanimate nature. It is ıtiful to see the shooting of a crystal;—to note, first, formation of integrant particles from their elements olution, and these, assuming a regular form under the ıence of attraction or crystalline polarity, producing eterminate shape; but the form is permanent. In different processes of elective attraction, and in fer- ıtation, we perceive a commotion, but in a little time products are formed, and the particles are at rest. ›re is in these instances nothing like the revolutions of the living animal substance, where the material is alternately arranged and decomposed. The end of this is, that the machinery of the body is ever new, and possesses a property within itself of mending that which was broken, of throwing off that which was useless, and of building up that which was insecure and weak; of repelling disease, or of controlling it, and substituting what is healthful for that which is morbid. The whole animal machinery we have seen to be a thing fragile and exposed to injury; without this continual change of material, and this new modelling of that material, our lives would be more precarious; the texture of our bodies would be spoiled like some fine piece of mechanism which had stopped, and no workman would have science sufficient to reconstruct it. But by this process, the minute particles of the body die successively; not as in the final death of the whole body, but part by part is deprived of its vitality and taken away into the general circulation, whilst new parts are endowed with the property of life, and are built up in their place. By this revolution, we see nature, instead of having to establish a new mode of action for every casualty, heals all wounds, unites all broken bones, throws off all morbid parts by the continuance of its usual operations; and the surgeon who is modest in his calling, has nothing to do but to watch, lest ignorance or prejudice interfere with the process of nature. This property of the living body to restore itself when deranged, or to heal itself when broken or torn, is an action which so frequently assumes the appearance of reason, as if it were adapting itself to the particular occasion, that even the last great luminary in this science, Mr. John Hunter, speaks of parts of the body, as "conscious of their imperfection," and "acting from the stimulus of necessity," thus giving the properties of mind to the body, as the only explanation of phenomena so wonderful.

We make a moderate assumption, when we declare these changes to be under the guidance of the living principle. In a seed, or a nut, or an egg, we know that there is life, and from the length of time that these bodies

·emain without change, we are forced to acknow- that this life is stationary or dormant, and limited : counteraction of putrefaction or chemical decom- on; but no sooner does this principle become ·, than a series of intestinal or internal changes are ienced, which are regularly progressive, without a ·nt's interruption, while life continues.

at principle which may continue an indefinite num- f days, months, or years, producing no change in is time, begins at once to exhibit its influence, : up the individual body, regulates the actions of ion and absorption; and, by its operation upon the ial of the frame, stamps it with external marks of :y, maturity, and age.

; let us examine the proofs of this universal change : material of the body. It is not very long since e was supposed to be a concrete juice, and that the parts were converted into solids, as we see mortar ris plaster from fluid assuming a solid form. But ıatomist began to observe, that the bones were s; that these pores admitted membranes and vessels; ›me went so far before their brethren, as to assert they saw arteries, veins, lymphatics, and nerves into the bone; in short, the opinion gradually stronger, that they were living parts, and subject the changes to which the softer parts of the living were liable. An accident gave admirable proof of It was found that the bones of pigs, fed with the of the dyer's vats, in which madder was contained, e tinged of a beautiful red colour. It was this fact ingenious physiologists made use of, and which ·d them to demonstrate the rapidity with which the ·ne was carried away, and new bone substituted. ·hysiologist observed, that if he threw a bone into e, what is called the animal part was burned and ıted, but there remained, imperishable by this pro- ı mass of earth, which proved to be the phosphate e. He thought of varying his experiment, and e bone into acid, which dissolved that phosphate ·, and left the bone to all outward appearance as before. It had its form, its membranes, its vessels, but when pressed it proved to be soft and pliant; the phosphate of lime having been dissolved and extracted, it was no longer capable of the office of a bone, to bear the weight and motions of the body. When the experiments with madder were resumed, it appeared that when this earth of bone was about to be secreted from the circulating vessels, and deposited in the membranes of the bone, it met with the colouring particles of the madder in the blood; and, as the chemist would explain, the madder and the phosphate of lime were precipitated, and filled all the interstices of the membranes and vessels. We shall not stop here to inquire into the admirable manner in which this hardening material of bone is deposited for the purposes of strength—it is only the change upon the material which we have now to contemplate.

If this earth of bone, so coloured, had beeen deposited for a permanency, and built into these cells and crevices, like brick and mortar, the colour would remain; but, however deeply the bones of an animal may be tinged in this manner, the colour is not permanent, unless the animal continue to be fed with the madder. If its food be pure of the madder, even for a few weeks, and if after this the animal be killed, its bones are white, that is to say, the old particles of phosphate of lime are carried away by absorption, and with them the colouring material; and that newer bone which is deposited by the arteries is untinged and pure, having no colouring material to attract.

It is unnecessary to follow out those curious experiments by which the physiologist has shown the rapidity of the formation of a new bone around the broken end of an old one, and the deep tinge such new bone takes, compared with the fainter colour of that which had been perfect, previous to the feeding with madder; the manner in which, by feeding the animal alternately with madder and without it, he contrives to exhibit different coloured layers in the growing bone. It is sufficient for our purpose, to know that the densest part of the animal frame is subject to change, like the most delicate texture of the body, and that the only means of arresting the motion is to deprive it of life; if a part of a bone be killed by the application of a cautery, that moment it becomes permanent, and is subject to no change, whilst all the parts around it are undergoing their revolutions.

The bones of the legs and thighs, which suffer the fatigue of motion, and which support the weight of the body, without diminishing in their length, or altering in the slightest measureable degree their proper form, are nevertheless undergoing an operation of repair, in which the old particles are withdrawn, whilst new ones replace them. We see with what care the walls of a house are shored up to admit of repair—how carefully the workman must estimate the strength of his pillars and beams—how nicely he must hammer in his wedges, that every interstice may be filled, and no strain permitted; and if this operation fail in the slightest degree, it is attended with a rent of the wall from top to bottom. We say, then, that by the very awkwardness of this process, in which, after all, there is danger of the whole fabric tumbling about the workmen, we are called upon to admire how the solid pillars in our own frame are a thousand times renewed, whilst the plan of the original fabric is followed to the utmost nicety in their restoration. And if it deviate at all, it is only in a manner the more to surprise us, since, on examination, it will be discovered to result from an adaptation of the strength of material to some new circumstance, the increasing weight it has to support, or the jar that it is subject to, from the change in the activity or exercise of the body.

There is a disease of the bone which illustrates this in a surprising manner, and proves to us, that however diseased and monstrous in its shape the bone may be, yet there is a natural law operating, which by its prevalence will overcome the morbid action, and from a shapeless mass restore the bone to its natural condition.

This disease is called *necrosis*, which word signifies the *death* of the bone merely; but it is death in very peculiar circumstances; a new bone is formed around the old one; a large and clumsy cylinder is fashioned of the earth of bone, in the hollow of which the shaft of the old bone is contained. After a long time the old bone comes out through this new case, and with the aid of the surgeon it is altogether withdrawn from the limb. During all this process the patient is capable of supporting his weight upon that limb, so that it resembles on a large scale that change which we have described as going continually on in the molecules of the bone; a new part is substituted, and the old taken away.

If workmen were to take away a pillar in the following manner, their work would resemble the process of necrosis: first, they must rear a hollow cylinder around the old pillar, resting on the plinth and base, and extending to the capital, and having secured the union of the cylinder at top and bottom to the extremities of the pillar, they must take away the shaft, or middle piece, of the old pillar by perforating the new cylinder.

The reader may easily imagine that when this process is completed in a man's limb, it will be as clumsy as the leg of an elephant, large, firm, and shapeless; but the extraordinary circumstance is still to be described.—This new bone is gradually diminished in its exterior surface, and its hollow filled up, and thus, by a change scarcely perceptible, it resumes the form and dimensions of the original bone; and, after a time, the anatomist might examine this limb and find neither in the articulating surfaces, nor in the spines and ridges, nor in the points of attachment for ligaments and muscles, any thing to indicate the extraordinary revolution that had taken place.

What explanation have we to give of this change? There can be no doubt that the material is not the same; for we have the old bone in our hand, and the man is walking upon a new bone. Yet extraordinary, then, as this appears, it is not more inexplicable than the common phenomenon of the growth of an infant to maturity. There is a living principle which is permanent while the material changes; and this principle attracts and arranges, dissolves and throws off successive portions of the solids. There is a law influencing this living principle, which, in its operation on the material, shapes and limits the growth of every part, and carries it through a regular series of changes, in which its form and aptness for its office are preserved, whilst the material alone is altered.

The influence of disease will for a time disorder this modelling process and produce tumours and distortions; but when at length the healthy action, that is, the natural action, prevails, these incumbrances are carried away, and the fair proportions of the fabric are restored.

It is very pleasing to observe the different means employed where a slight change of circumstances demands it. This earth of bone—the phosphate of lime—is changing continually; but the teeth admit of no change; they consist of earth too—the phosphate, carbonate, and fluate of lime. Bodies calculated for such violent attrition, and with a surface so hard as to strike fire with steel, would be ill accommodated with such a property of changing as we have seen in the bones. They must therefore fall out and be succeeded by new ones; and this process, familiar as it may be, is very curious when philosophically considered.

There are no teeth whilst yet the infant is at the breast; and when they rise they are attended with new appetites, and a necessity for change of food. When perfected they form a range of teeth, neat and small, adapted to the child's jaws and the size of its bones. Were they to grow at once, or to fall out at once, it would prove a disturbance to the act of eating. They fall in succession; their fangs are absorbed, they are loose and jangling, and are easily extracted. But now comes the question, why are these teeth of the infant old at six years? Why are those that are to succeed and be stationary for a series of years, to germinate and grow at the appointed time like the buds in the axilla of a leaf? And when fully formed, why do they remain perfect for sixty years instead of six; at the end of which term the first set were old and decayed? No difference can be observed in the material of the teeth of the first or second set. The one will be as perfect as the other after remaining a hundred years in a charnel house. Can any one refuse his belief, then, when he sees so accurate a mechanical adaptation of the teeth to their places and their offices; can he, we say, refuse assent to this also, that there is a law impressed—a property by which the milk teeth shall fail and be discharged from the jaw in six years, whilst the others will last the natural life of the adult, if not injured by accidents to which all parts are subject? This is not the only instance in which parts of the body lie dormant for a term of years, and are at a particular period of life developed and perfected—and which have, we may say, their time of infancy, perfection, and decay, whilst yet there is no material deterioration observable in the general frame.

We are thus brought to the consideration of a question which has not yet been fairly stated.

Those who say that life results from structure, and that the material is the ruling part, bid us look to the contrast of youth and age. The activity of limb and buoyancy of spirit they consider as a necessary consequence of the newness and perfection of organization in youth. On the other hand, a ruined tower, unroofed, and exposed to be broken up by alternation of frost and heat, dryness and moisture, wedged by the roots of ivy, and tottering to its fall, they compare with old age—with the shrunk limbs, tottering gait, shrivelled face, and scattered grey hair of the old.

But in all this there is not a word of truth. Whilst there is life and circulation there is change of the material of the frame (and there is a sign of this if a broken bone unites or a wound heals). Ascribe the distinction to the rapidity of change, to the velocity of circulation, or to the more or less energy of action; but with the antiquity of the material it can have nothing to do. The roundness and fulness of flesh, the smoothness, transparency, and colour of the cheek, belong to youth, as characteristic of the time of life, not as a necessary quality of the material! Is there a physiognomy in all nature—among birds and beasts, and insects and flowers—and

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We might as well consider the differ-
of life of the annual or biennial plant as
ıe oak, or the ephemeris fly as compared
at hawks at it, to be in the qualities of
forms them, as that the outward cha-
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ıidance of Providence; but it is more
greeable to our self-importance, it gives

us more confidence in that Providence, to discover that the minutest changes in nature are equally His care, and that "all things do homage."

Although it be true that every thing in nature, being philosophically contemplated, will lead to the same conclusions, yet the occurrences around us steal so imperceptibly on our observation, all the objects of nature, or at least vegetable and animal productions, grow up by so slow a process by our side, that we do not consider them at all in the same way as we should do if they started suddenly upon our vision.

It is this familiarity with the qualities of a living body, and a habit of seeing without reflection, which has made it necessary to carry the reader through so long a course of observation and reasoning to excite attention to the admirable structure of his own frame, and its adaptation to the earth we inhabit—to perceive that every thing is formed with a strict relation to the human faculties and organs, to extend our dominion and to multiply our sources of enjoyment. It is by seeing the plan of Providence in the establishment of relations between the condition of our being and the material world, that we learn to comprehend that unity of design in the creation in which we form so great a part.

This exaltation of our nature is not like the influence of pride or common ambition. We may use the words of Socrates to his scholar, who saw in the contemplation of nature only a proof of his own insignificance, and concluded "that the gods had no need of him," which drew this answer from the sage: "The greater the munificence they have shown in the care of thee, so much the more honour and service thou owest them!"

END OF VOLUME IV.

M. L.

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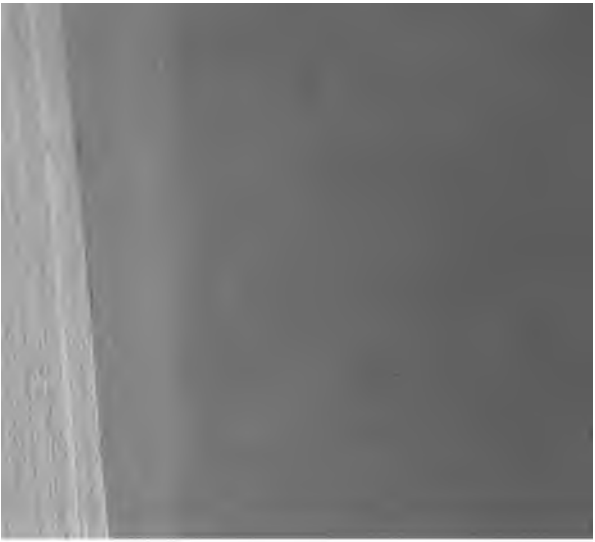

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